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THE MOSQUITOES OF NEW JERSEY

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THE MOSQUITOES OF NEW JERSEY AND THEIR CONTROL

By THOMAS J. HEADLEE

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1945

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PRINTED IN THE UNITED STATES OF AMERICA

To the memory of

JOHN B. SMITH

Pioneer in mosquito
control in New Jersey

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Errata

ON PAGE 12 under "Names According to John B. Smith" reference numbers 21, 22, 24 should read 23, 24, 26. On page 13 under "Names According to Howard, Dyar and Knab" reference number 12 should read 14 and under "Names According to N. J. Agr. Sta. Bul. 348" reference number 8 should read 10. On page 14 under "Names According to Robert Matheson" reference number 16 should read 18. On page 175 reference number 12 should read 14, and on page 318 reference number 5 should read 7.

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INTRODUCTION

SINCE THE MOSQUITO WORK of the New Jersey Agricultural Experiment Station was begun by Dr. John B. Smith in 1900, three substantial mosquito publications of a general nature have been published by the station. The first, issued in 1904, was Dr. Smith's monumental report on mosquitoes occurring within New Jersey, their habits, life history, etc. Since then the station has issued Bulletin 276 in 1915 and Bulletin 348 in 1921, supplementing the information in Dr. Smith's report. These were primarily for the use of practical mosquito control workers. They are out of print, and the needs of mosquito control work in this state demand that a new and up-to-date publication be issued.

There is included in this book such information about mosquitoes, their description, life histories, breeding places, food, natural enemies, and control as to furnish scientific investigator and practical mosquito worker alike with fundamental information, necessary to a proper understanding of mosquitoes and their control. While the subject matter of this publication is primarily scientific, it is intended to be of value not only to teacher, student, and those engaged in practical mosquito work, but to the lay reader as well.

The publication of this book was made possible by the cooperation of the New Jersey Mosquito Extermination Association, the several county mosquito extermination commissions, and the New Jersey Agricultural Experiment Station. My sincere appreciation is herewith expressed to the members and executives of the county mosquito commissions, to the staff of the Entomology Department of the New Jersey Agricultural Experiment Station, to my associates in other departments, and to all others who have assisted in collecting and preparing subject matter, checking manuscript, and reading proof.

Acknowledgment is hereby given to Howard, Dyar, and Knab, whose publication *Mosquitoes of North and Central America and the West Indies*, has furnished descriptions of several species of mosquitoes needed to complete the chapter on Mosquito Biology. Practically the entire chapter on Mosquito Biology was taken directly from Dr. Smith's

1904 Report, because the investigations conducted by him and his assistants in those pioneer days of mosquito work were so fundamentally sound that for the most part they are still the basis for present-day mosquito control.

Thomas J. Headlee

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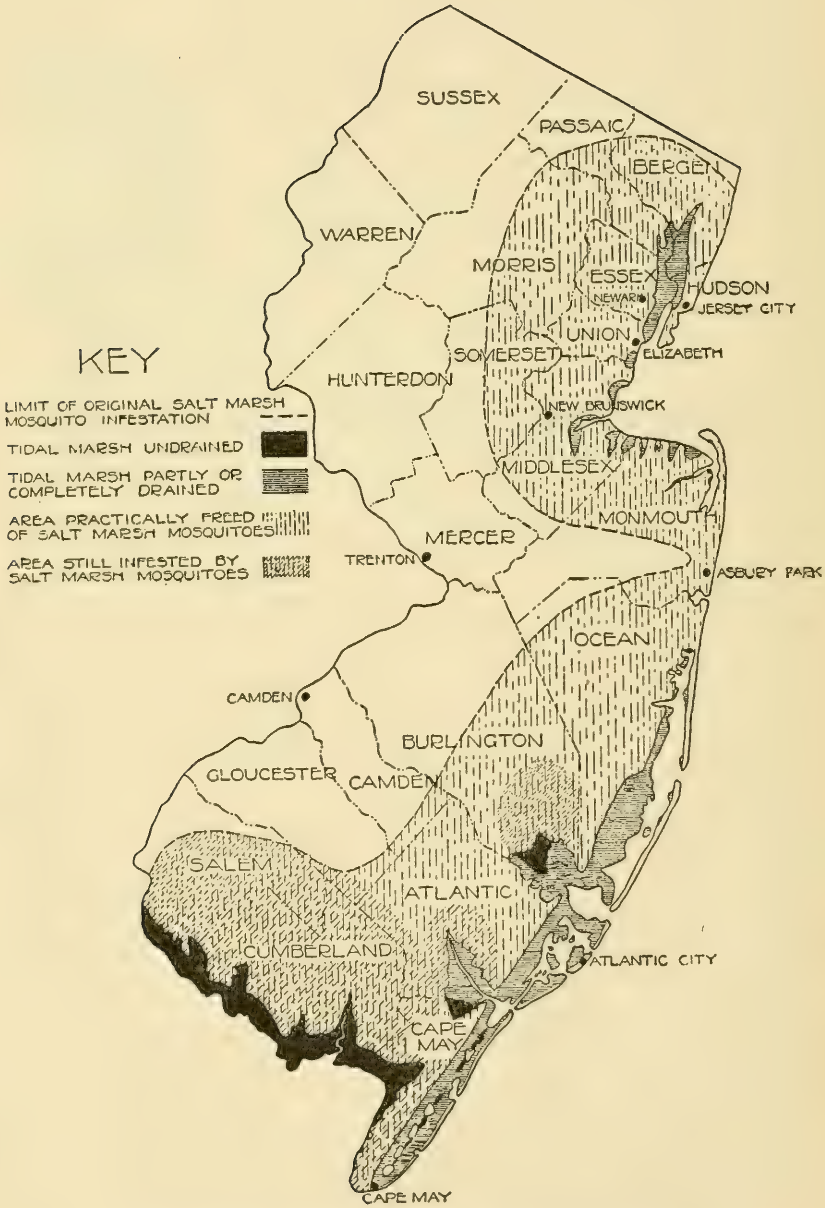
THE MOSQUITOES OF NEW JERSEY


KEY
LIMIT OF ORIGINAL SALT MARSH MOSQUITO INFESTATION
TIDAL MARSH UNDRAINED
TIDAL MARSH PARTLY OR COMPLETELY DRAINED
AREA PRACTICALLY FREED OF SALT MARSH MOSQUITOES
AREA STILL INFESTED BY SALT MARSH MOSQUITOES
SUSSEX
PASSAIC
BERGEN
WARREN
MORRIS
ESSEX
NEWARK
HUDSON
JERSEY CITY
UNION
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MONMOUTH
MERCER
TRENTON
ASBURY PARK
OCEAN
CAMDEN
BURLINGTON
GLOUCESTER
CAMDEN
SALEM
ATLANTIC
CUMBERLAND
ATLANTIC CITY
CAPE MAY
CAPE MAY

Salt marsh, mosquito breeding conditions, 1940.

1

VALUE OF MOSQUITO CONTROL

NEW JERSEY has roughly the shape of an hourglass, is 169.5 miles from Cape May City to Port Jervis and has a minimum width of 31.5 miles between the Delaware River at Trenton and Raritan Bay on the east coast. The northern section consists of low mountains and valleys with many rugged streams. The mountains disappear by the time the latitude of Trenton and New Brunswick are reached, and the southern portion of the hourglass is nearly all a comparatively level coastal plain except the Monmouth highlands extending southwestward from Sandy Hook in Monmouth County. Along the upper regions of the Hackensack River and extending along Newark Bay, Arthur Kill, Raritan Bay, Atlantic Ocean, and Delaware Bay this coastal plain is bordered very generally with low-lying salt marshes of which, according to the Geological Report of the State of New Jersey for 1895, there are 296,000 acres.

Woodland pool and fresh water swamp mosquitoes occur generally throughout the northern, and to a less extent, southern section of the state. Salt marsh mosquitoes breed everywhere salt marshes are located, and because they can fly over adjacent uplands, cover so large a section of the coastal and bay borders as to infest the territory on which three-fourths of the state's population lives. The house mosquito's abundance appears to be correlated with the presence and density of human population.

Transportation is historically a factor having much influence, even on agricultural development. In the days of New Jersey's early settlement water-borne transportation was dominant, and consequently the early settlements were made first upon such good land as lay adjacent to navigable water courses, where trade could be carried on. The two outstanding navigable waters consisted of a group of bays, inlets, and rivers in the neighborhood of New York and Newark Bay and of the Delaware Bay and River. Hence, we have the great metropolitan districts around New York and Philadelphia.

This mosquito situation was well appreciated in early times. Dr. Ralph Hunt (15) quotes a considerable number of records which serve to give some idea of the abundance of the mosquito pest, principally in the northeastern part of New Jersey but also to some extent elsewhere.

Max Schalish, speaking of New Sweden near the mouth of the Delaware River, in 1627, said: "Swedes built a fort called Mockeborg, because of the numberless mosquitoes infesting the region."

In 1748 Peter Kalm wrote: "The gnats, which are very troublesome at night here, are called mosquitoes. They are exactly like the gnats in Sweden, only somewhat smaller. In the daytime or at night they come into the houses and when the people have gone to bed they begin their disagreeable humming, approach nearer to the bed, and at last suck up so much blood that they can hardly fly away. Their bite causes blisters on people with delicate skins.

"When the weather has been cool for some days, the mosquitoes disappear. But when it changes again, and especially after a rain, they gather frequently in such quantities about the houses that their numbers are astonishing. The chimneys which have no valves for shutting them out afford the gnats a free entrance into the house of the English. On sultry evenings the mosquitoes accompany the cattle in great swarms from the woods to the houses, or to town, and when the cattle are driven past the houses the gnats fly in wherever they can.

"In the greatest heat of the summer they are so numerous in some places that the air seems to be quite full of them, especially near swamps and stagnant water, such as the river Morris in New Jersey. The inhabitants therefore make a big fire before the houses to expel these disagreeable guests by the smoke."

Regarding Elizabethtown Point Peter Kalm said again in 1748: "The country was low on both sides of the river, and consisted of meadows. But there was no other hay to be got, than such as commonly grows in swampy grounds; for as the tide comes up in this river, these low plains were sometimes overflowed when the water was high.

"The people hereabouts are said to be troubled in summer with immense swarms of gnats or musquetoes which sting them and their cattle. This was ascribed to the low swamp meadows, on which these insects deposit their eggs, which are afterwards hatched by the heat."

Again concerning Elizabethtown Point in New Jersey in 1783–1784 Dr. John David Schoepf said: "Surrounded of millions of musquetoes we were obliged to spend the time until daybrake on the deck of the little vessel. These marshy coasts are the favorite sojourning places of musquetoes, more than usually numerous this year as a result of moist and rainy weather, and grown to an unusual size. Whoever has made the acquaintance of these small enemies of the night's rest will know that the buzzing of a few of them is sufficient to banish sleep for hours. I had covered myself with a cloak, and a thick sail, and the night being extremely warm I suffered as in a perfect sweat-bath, but the musquetoes found their way through. The complete stillness of the night gave them liberty to swarm about at will, for in windy weather they do not appear, and when high cold winds set in from the northwest such regions as these are for a time swept of musquetoes, either benumbed by the cold or carried out to sea.

"After daybrake we were taken to the house of the man who owns the ferry, the only ferry thereabouts, a few hundred yards from the landing place, but not beyond the territory of the musquetoes. Before the door stood a great vat in which a wet-wood fire was kindled; the musquetoes were kept off by the smoke in which the people of the place were making themselves comfortable. The owner of the ferry was a doctor, no less, and admitted with the greatest candor that he had chosen such an infernal situation only with the praiseworthy design of making, that is gaining money."

J. B. Brissot de Werville in 1788 said: "The road from New York to Newark is in part over a marsh; I found it really astonishing; it recalls to mind the indefatigable industry of the ancient Dutch settlers mentioned by Mr. de Crevecoeur. Built wholly of wood, with much labour and perseverance in the midst of water, on a soil that trembles under your feet, it proves to what point may be carried the patience of man, who is determined to conquer nature.

"But though much of these mashes are drained, there remains a large extent of them covered with stagnant waters, which infect the air, and give birth to these musquitoes with which you are cruelly tormented, and to an epidemical fever which makes great ravages in summer; a fever known likewise in Virginia and in the southern states, in parts adjacent to the sea."

Dr. William Currie of Philadelphia in 1792 said: "The flat and marshy parts of this State (New Jersey) which are very numerous are infested with myriads of musquetoes which give intolerable annoyance to man and beast. Their bites often occasion an Erysipelas, both painful and dangerous. These insects, however, are never observed when the mercury is below the 60°. I do not know the degree of cold which renders bugs inactive, but have been kept awake by them at Salem as late as the tenth of November."

Thus it appears that in early days from 1637 to 1850 the pest mosquitoes, undoubtedly salt marsh species, were extremely and seriously troublesome throughout the entire coastal area of the Atlantic Ocean and Delaware Bay.

Although a considerable amount of anti-mosquito work had been done in the Newark Bay marshes prior to 1913 the writer saw a tremendous brood from the Newark Bay marshes about July 15, 1913 sweep over the adjacent upland, reaching as far north as Morristown and north of Paterson. Again in 1914 the same thing occurred about the same time of year and simply blanketed with mosquitoes the entire area from the marshes to and across the first range or two of mountains. He recalls one early evening at the Market Street Station in Newark where the station was so filled with mosquitoes that passengers were everywhere slapping and salt marsh mosquitoes could be seen resting in large numbers on the inside walls of the station. There were many instances in the early years when mosquitoes came into Newark and Jersey City and penetrated the stores in such numbers that they had to be swept out of the show windows after they died.

Evidently the mosquitoes in northern New Jersey, particularly in Newark, were originally as abundant and troublesome as they are now known to be in certain areas of the Bay Coast. In fact, the location of the Newark Bay salt marshes with regard to prevailing winds should give Newark about as great a supply of mosquitoes before any work was done against them as Cedarville originally got from certain marshes of the Delaware Bay.

Out of the total catch of 183,096 *Aëdes sollicitans* in thirty-five traps, for five successive years from 1932 to 1936 inclusive, 97,964, or a little more than half of the total, were taken in a single trap located at Cedarville in Cumberland County. The traps were located at two points in Sussex County, one in Morris, two in Passaic, three in Bergen, four in Hudson, four in Essex, two in Union, four in Middlesex, two in Monmouth, five in Ocean, four in Atlantic, four in Cape May, one in Cumberland, and one in Salem.

If we may assume that originally the infestation in and about Newark was as bad as it has been until the end of 1936 about Cedarville and that the largest catch in that area in the five years above mentioned was 1,078, the reduction due to anti-mosquito work in the Newark area runs about 98.9 per cent. The great salt marsh broods that used to rise from the Newark Bay, Hackensack, and Staten Island marshes and blanket the entire area between the marshes and the mountains to the northwest, north and northeast have disappeared and this disappearance must be ascribed to anti-mosquito work.

Atlantic County has as much salt marsh as any other county in the state, amounting to 53,325 acres as stated in the Report of the Geologist for 1895. Ocean County has 40,400 and Burlington County has 9,943. Cape May County has about 53,368 acres. It is an undeniable fact that Atlantic County salt marsh is better and more completely ditched than the counties immediately north or the county immediately south. The county immediately to the north on which we have figures is Ocean and the average catch in five traps for five years was 5,062. In Atlantic County the average catch in four traps for five years was 4,381 while in Cape May, which lies immediately to the south of Atlantic, four traps in five years show an average of 6,228, clearly indicating that reduction of salt marsh mosquitoes is best where the ditching is most complete.

Through the agency of the Civilian Conservation Corps camp located near Cedarville in the season of 1936, 1,531,391 feet of ditching were cut or recut in the salt marshes lying off Cedarville. For the years from 1932 to 1936 inclusive the Cedarville mosquito trap caught an average of 19,592 females per year. In 1937, after this limited amount of ditch cutting had been done in the neighborhood of Cedarville, the total catch was 5,790 female *sollicitans*, or a reduction of seventy per cent. The correlation between salt marsh mosquito ditching and reduction in salt marsh mosquitoes seems definite and thus again it appears that anti-mosquito work has produced enormous reduction in the salt marsh mosquito population and that the greatest reductions are present where salt marsh anti-mosquito work is the most complete.

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STRUCTURE, CLASSIFICATION, AND KEYS

FROM THE STANDPOINT OF MOSQUITO SUPPRESSION, a knowledge of mosquito species is invaluable. Not only are the necessary control methods determined by the habits of the specific troublesome species but one cannot reach a true estimate of the results of the work without this knowledge. Since mosquitoes fly, or are wind carried, often for some distance, locality is not a determining factor. If the troublesome.mosquitoes are really salt marsh species, a knowledge of that fact would prevent the useless expenditure of time and money on control of local breeding. If, in spite of all work which a municipality can do, locally it is overrun with mosquitoes a knowledge of that species will enable one to trace them to their breeding place. Very essential is a knowledge of external anatomy which will help one to understand the artificial keys used in separating the species.

In order to determine the species by its appearance familiarity with characteristic marks is important. Much the same thing is true of classifying the larvae. The inability of the larva to migrate is offset, to some extent, by the ubiquitous breeding habits of certain species. In general, the woodland species are found in woodland pools; the swamp species are likely to be prevalent in the swamps. The malarial species are likely to breed in reasonably clear water along the overgrown banks of streams, pools, and small lakes. In stagnant pools in the open or about human habitations house mosquitoes are likely to be prevalent. The salt marsh is the likeliest home of the salt marsh species. But there is sufficient overlapping of one species on the territory of another to keep the student constantly on the lookout for the unexpected.

Adult or perfect mosquitoes can be successfully classified only when they are killed without crushing. For identification the mosquito is in the best condition when it has emerged from the pupal shell and has had time (twenty-four hours) to harden. From that time forward, the markings decrease in clearness through fading and rubbing until, in specimens that have been on the wing seven or eight weeks, the really characteristic marks disappear, and determination becomes difficult, if not impossible. Regardless of the period in adult life when the mosquito is caught for classification purposes, it should always be placed, without touching with the hand, in a cyanide jar or other gas killing apparatus. As soon as dead it should be emptied on a layer of very loose cotton. Unless it can be pinned within twenty-four hours it should be placed in a relaxing box (moist chamber humidor). When ready it should be laid on a smooth surface and pinned through the side of the thorax, a method which the writer prefers, because absolutely no handling of the specimen is required. The common method is to thrust the pin through the thorax from top to bottom. By use of a spacer the insect should be slipped up the pin until thumb and finger can grasp the head without touching any part of the insect. The date and locality label should then be slipped up the pin to a point in clear view. The completed specimen is then thrust into the cork bottom of a tight box furnished with naphthalene to protect the mosquito against museum pests. In this way mosquito specimens may be preserved indefinitely. If storage is not desired the preparation may be stopped with the pinning.

Larval mosquitoes can be classified with certainty only as they are prepared for use under the microscope, or each individual separated out and allowed to breed through to an adult. In the field, larvae may be scooped up with a dipper, and placed in vials filled with eighty per cent alcohol. In this way they will remain in condition for study for a long period. At any time specimens may be removed and mounted on a glass slide for study. Of course, still better conditions may be obtained by bringing the larvae in alive and dropping them into hot absolute alcohol. After giving time for the alcohol to remove the water in their bodies (ten minutes when the number of specimens is small, and the volume of alcohol large) they should be placed in xylol for clearing. When sufficiently clear they may be mounted directly on slides in Canada balsam. When properly carried out, this process gives specimens that will last indefinitely.

The mosquito's body, like that of most insects, is made up of three distinct regions—head, thorax, and abdomen. The head is a globular object having: a pair of eyes, one on each side; a pair of more (male) or less (female) feathery feelers, antennae; a pair of mouth feelers, or *palpi;* and a long prominent beak. The thorax is wedge-shaped, broader above than below, and bears three pairs of legs on its lower surface and one pair of transparent wings on its upper surface. The upper surface (dorsal aspect) of the thorax is elongate, elliptical, and is formed mostly of mesonotum. Traces of a pronotum and of a scutellum appear at the front and rear edges of the mesonotum respectively. The abdomen is long and narrow and composed of many plainly defined segments. At the tip are small appendages, part of the sexual apparatus; a knowledge of these is not required for elementary classification.

Each leg consists of a small *coxa* and *trochanter* which (Fig. I), are so hidden by the body as not to show, a long *femur*, and equally long *tibia*, and a five-jointed foot, or *tarsus*. The last joint is tipped with claws. The claw formula as used by Howard, Dyar, and Knab is explained as follows: the first two figures indicate spurs on the two claws of the prothoracic foot, the second two the claws on the mesothoracic foot, and the last two figures indicate spurs on the two claws of metothoracic foot.

The wings have scales along the veins. The color and arrangement of these scales determines whether the wing appears uniform, or spotted and mottled.

When an infesting brood of mosquitoes has been analyzed and traced as nearly as possible to the place of origin, it is necessary to determine what species of larvae are found in the pools. If they are identical with those of principal members of the winged brood, the proof of source is complete. Furthermore, when larvae are found, it is not possible to judge whether they need treatment unless the kind of mosquitoes which they will produce is known. It is therefore important to be able to recognize them readily, by familiarity with the external features.

The larvae has the same three divisions of the body as the adult. The head has eyes, antennae, and rotary mouth brushes. A small bunch of hairs on each antenna is called the antennal tuft. Various tufts of bristles scattered over the thorax are known as the thoracic tufts. The abdomen consists of one small and eight well developed segments, each of which bears some tufts of bristles, known as the abdominal hair tufts. The eighth segment has grown a dorsal process known as the air-tube, or siphon, with a double row of spines on its posterior surface and the opening of the breathing system at its tip. In nearly all species this tube is used to penetrate the water surface-film and to reach the atmospheric air. On each side of the eighth segment there is a little patch of scales that is much used in classification. The small ninth segment has a large group of bristles, the anal tuft or posterior or ventral brush, and some smaller tufts. The anal opening is situated at the outer end of this segment and the tracheal gills extend outward from this opening.

Because of the many changes in names of species a list of New Jersey

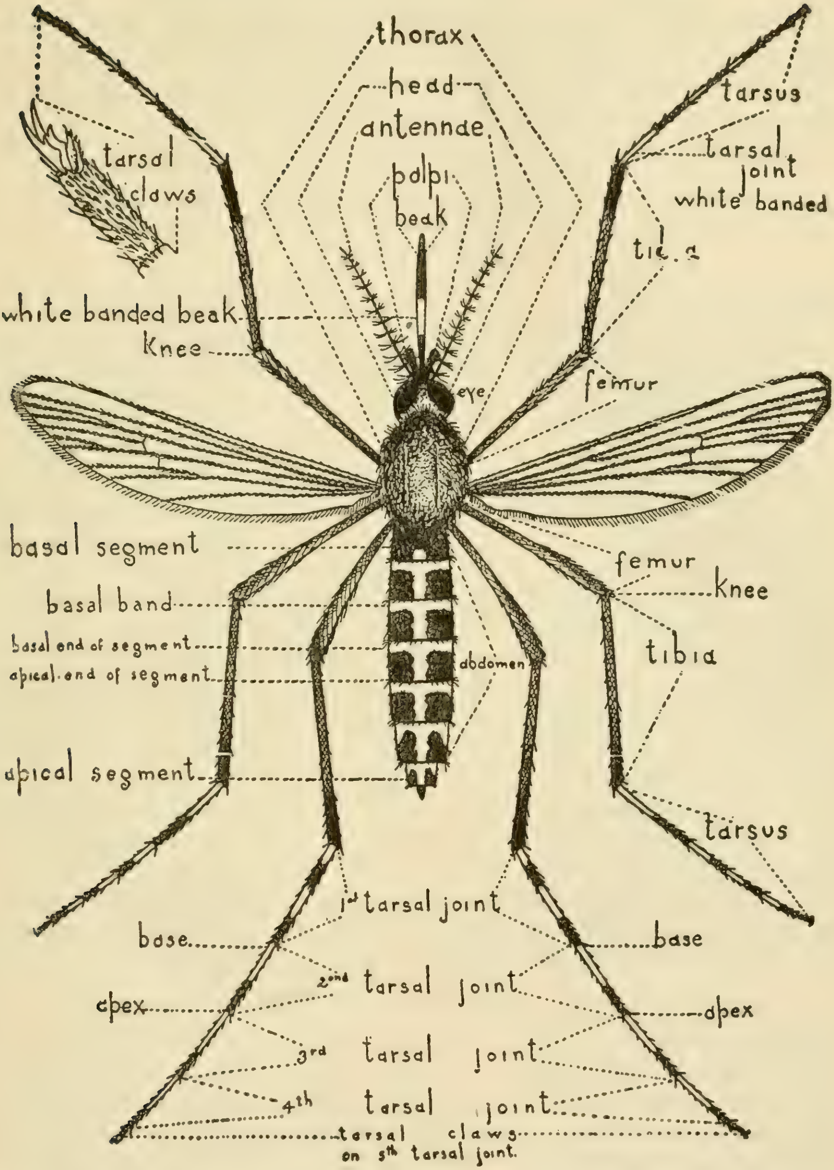
thorax
head
antennae
palpi
beak
tarsus
tarsal joint white banded
tarsal claws
tibia
white banded beak
knee
eye
femur
basal segment
femur
knee
basal band
tibia
basal end of segment
apical end of segment
abdomen
apical segment
tarsus
1st tarsal joint
base
base
2nd tarsal joint
apex
apex
3rd tarsal joint
4th tarsal joint
tarsal claws on 5th tarsal joint.

FIG. 1. Adult of *Aëdes sollicitans* with parts named. (After John B. Smith.)

species is submitted in which the change from the old to the less familiar new name is specified. Some sort of artificial key is necessary for the determination of species of mosquitoes. Practical work has shown the need of the two types of keys.

The first will involve the use of microscopic characters and is intended primarily for laboratory use. It will enable the worker to identify almost any species found in the state. The second involves characters which can be determined by the eye, aided by an ordinary hand lens, and is intended for use in the field. The former type of key is given first (keys 1 and 2) and the latter second (keys 3 and 4).

NAMES ACCORDING TO JOHN B. SMITH
(21, 22, 24)

Number	*Scientific*	*Common*
1	Culex siphonalis Grossb.	Brown-Striped Woods Mosquito
2	Culex punctor Grossb.	Unbanded-Legged Woods Mosquito
3	Culex serratus Theob.	Silver-Striped Mosquito
4	Culex atropalpus Coq.	Rock Pool Mosquito
5	Culex aurifer Coq.	Golden-Scaled Mosquito
6	Culex canadensis Theob. (C. niveitarsis Coq.)	Woodland Pool Mosquito
7	Culex cantator Coq.	Brown Salt Marsh Mosquito
8	Aëdes fuscus O.S.	Little Smoky Mosquito
9	Culex dupreei Coq.	Dupree's Mosquito
10*	Culex sylvicola Grossb.	Scaly-Winged Mosquito
11	Culex pretans Grossb.	Brown-Striped Mosquito
12	Culex sollicitans Walk.	White-Banded Salt Marsh Mosquito
13	Culex cantans Meig.	Brown Woods Mosquito
14	Culex taeniorhynchus Wied.	Small Salt Marsh Mosquito
15	Culex triseriatus Say	Tree-Hole Mosquito
16	Culex trivittatus Coq. (C. inconspicous Grossb.)	Three-Striped Mosquito
17	Culex sylvestris Theob.	Swamp Mosquito
18	Anopheles barberi Coq.	Tree-Hole Anopheles
19	Anopheles crucians Wied.	Daylight Anopheles
20	Anopheles punctipennis Say	Mottled Wing Anopheles
21	Anopheles maculipennis Meig.	Four-Spotted Anopheles
22		
23	Culex territans Walk.	Little Black Mosquito
24	Culex dyari Coq.	
25	Culex melanurus Coq.	Black-Tailed Mosquito
26	Culex pipiens Linn.	House or Rain Barrel Mosquito
27	Culex salinarius Coq.	Unbanded Salt Marsh Mosquito
28	Culex restuans Theob.	White-Dotted Mosquito
29	Culex perturbans Walk.	Irritating Mosquito
30	Culex signifer Coq.	White-Lined Mosquito
31	Psorophora ciliata Fabr.	Fringed-Legged Mosquito
32	Culex jamaicensis Theob.	Spotted-Legged Mosquito
33	Culex discolor Coq.	Mottled Mosquito
34	Janthinosoma musica Say	Big Woods Mosquito

* *Culex squamiger* of the 1904 Report was listed erroneously. The identification was incorrect, as *Culex squamiger* is a Pacific salt marsh species. Smith makes this correction in his 1905 Report.

NAMES ACCORDING TO JOHN B. SMITH (*Continued*)

35	Uranotaenia sapphirina O.S.	Sapphire-Lined Mosquito
36	Wyeomyia smithii Coq.	Pitcher Plant Mosquito

	NAMES ACCORDING TO HOWARD, DYAR AND KNAB (12)	NAMES ACCORDING TO N. J. AGR. STA. BUL. 348 (8)
Number	*Scientific*	*Scientific*
1	Aëdes abfitchii (Felt) D. & K.	Aëdes abfitchii Felt
2	Aëdes abserratus (Felt & Young) Morse	Aëdes abserratus Felt
3	Aëdes atlanticus D. & K.	Aëdes atlanticus D. & K.
4	Aëdes atropalpus (Coq.) D. & K.	Aëdes atropalpus Coq.
5	Aëdes aurifer (Coq.) D. & K.	Aëdes aurifer Coq.
6	Aëdes canadensis (Theob.) D. & K.	Aëdes canadensis Theob.
7	Aëdes cantator (Coq.) D. & K.	Aëdes cantator Coq.
8	Aëdes cinereus Meig.	Aëdes fuscus Walk.
9	Aëdes dupreei (Coq.) D. & K.	Aëdees dupreei Coq.
10	Aëdes grossbecki D. & K.	Aëdes grossbecki D. & K.
11	Aëdes hirsuteron Theob.	Aëdes hirsuteron Theob.
12	Aëdes sollicitans (Walk.) D. & K.	Aëdes sollicitans Walk.
13	Aëdes stimulans Walk.	Aëdes stimulans Walk.
14	Aëdes taeniorhynchus (Wied.) Busck	Aëdes taeniorhynchus Say
15	Aëdes triseriatus (Say) D. & K.	Aëdes triseriatus Say
16	Aëdes trivittatus (Coq.) D. & K.	Aëdes trivittatus Coq.
17	Aëdes vexans Meig.	Aëdes sylvestris Theob.
18	Coelodiazesis barberi (Coq.) D. & K.	Anopheles barberi Coq.
19	Anopheles crucians Wied.	Anopheles crucians Wied.
20	Anopheles punctipennis Say	Anopheles punctipennis Say
21	Anopheles quadrimaculatus Say	Anopheles quadrimaculatus Say
22		
23	Culex saxatilis Grossb.	Culex territans Walk.
24	Culex dyari Coq.	Culex dyari Coq.
25	Culex melanurus Coq.	Culex melanurus Coq.
26	Culex pipiens Linn.	Culex pipiens Linn.
27	Culex salinarius Coq.	Culex salinarius Coq.
28	Culex territans Walk.	Culex restuans Theob.
29	Mansonia perturbans (Walk.) D. & K.	Mansonia perturbans Walk.
30	Orthopodomyia signifer Coq.	Orthopodomyia signifer Coq.
31	Psorophora ciliata Fab.	Psorophora ciliata Fab.
32	Psorophora columbiae D. & K.	Psorophora columbiae D. & K.
33	Psorophora discolor Coq.	Psorophora discolor Coq.
34	Psorophora sayi D. & K.	Psorophora sayi D. & K.
35	Uranotaenia sapphirina O.S.	Uranotaenia sapphirina O.S.
36	Wyeomyia smithii (Coq.) Felt	Wyeomyia smithii Coq.

NAMES ACCORDING TO ROBERT MATHESON

(16)

Number	*Scientific*
1	Aëdes excrucians Walk.
2	Aëdes abserratus Felt
3	Aëdes atlanticus D. & K.
4	Aëdes atropalpus Coq.
5	Aëdes aurifer Coq.
6	Aëdes canadensis Theob.
7	Aëdes cantator Coq.
8	Aëdes cinereus Meig.
9	Aëdes dupreei Coq.
10	Aëdes grossbecki D. & K.
11	Aëdes hirsuteron Theob.
12	Aëdes sollicitans Walk.
13	Aëdes stimulans Walk.
14	Aëdes taeniorhynchus Wied.
15	Aëdes triseriatus Say
16	Aëdes trivittatus Coq.
17	Aëdes vexans Meig.
18	Anopheles barberi Coq.
19	Anopheles crucians Coq.
20	Anopheles punctipennis Say
21	Anopheles quadrimaculatus Say
22	
23	Culex apicalis Adams
24	Theobaldia morsitans Theob.
25	Culex melanura Coq.
26	Culex pipiens Linn.
27	Culex salinarius Coq.
28	Culex territans Walk.
29	Taeniorhynchus perturbans Walk.
30	Orthopodomyia signifer Coq.
31	Psorophora ciliata Fabr.
32	Psorophora columbiae D. & K.
33	Psorophora discolor Coq.
34	Psorphora posticata Wied.
35	Uranotaenia sapphirina O.S.
36	Wyeomyia smithii Coq.

NAMES ACCORDING TO THIS BOOK

Number	*Scientific*	*Common*
1	Aëdes excrucians Walker	Brown-Striped Woods Mosquito
2	Aëdes implacabilis Walker	Red-Backed Mosquito
3	Aëdes atlanticus D. & K.	Silver-Striped Mosquito
4	Aëdes atropalpus Coq.	Rock Pool Mosquito
5	Aëdes aurifer Coq.	Golden Scaled Mosquito

NAMES ACCORDING TO THIS BOOK (*Continued*)

6	Aëdes canadensis Theob.	Woodland Pool Mosquito
7	Aëdes cantator Coq.	Brown Salt Marsh Mosquito
8	Aëdes cinereus Meig.	Little Smoky Mosquito
9	Aëdes dupreei Coq.	Dupree's Mosquito
10	Aëdes grossbecki D. & K.	Scaly Winged Mosquito
11	Aëdes sticticus Meigen	Brown-Striped Mosquito
12	Aëdes sollicitans Walk.	White-Banded Salt Marsh Mosquito
13	Aëdes stimulans Walk.	Brown Woods Mosquito
14	Aëdes taeniorhynchus Wied.	Small Salt Marsh Mosquito
15	Aëdes triseriatus Say	Tree-Hole Mosquito
16	Aëdes trivittatus Coq.	Three Striped Mosquito
17	Aëdes vexans Meig.	Swamp Mosquito
18	Anopheles barberi Coq.	Tree-Hole Anopheles
19	Anopheles crucians Wied.	Daylight Anopheles
20	Anopheles punctipennis Say	Mottled Wing Anopheles
21	Anopheles quadrimaculatus Say	Four-Spotted Anopheles
22	Anopheles walkeri Theob.	Walker's Anopheles
23	Culex apicalis Adams	Little Black Mosquito
24	Theobaldia morsitans Coq.	Dyar's Mosquito
25	Theobaldia melanurus Coq.	Black-Tailed Mosquito
26	Culex pipiens Linn.	House or Rain-Barrel Mosquito
27	Culex salinarius Coq.	Unbanded Salt March Mosquito
28	Culex territans Walk.	White Dotted Mosquito
29	Mansonia perturbans Walk.	Irritating Mosquito
30	Orthopodomyia signifera Coq.	White-Lined Mosquito
31	Psorophora ciliata Fabr.	Fringed-Legged Mosquito
32	Psorophora columbiae D. & K.	Spotted-Legged Mosquito
33	Psorophora discolor Coq.	Mottled Mosquito
34	Psorophora ferox Humboldt	Big Woods Mosquito
35	Uranotaenia sapphirina O.S.	Sapphire-Lined Mosquito
36	Wyeomyia smithii Coq.	Pitcher Plant Mosquito
37	Megarhinus septentrionalis D. & K.	Long-Beaked Mosquito

KEY NUMBER 1

A Key to New Jersey Species of Adult Female Mosquitoes

1a Palpi of female nearly as long as the beak: Tribe *Anophelini*: 2
Palpi two-thirds length of proboscis, four-jointed, stout, and
more or less laterally compressed; beak strongly curved: The
1b Long-Beaked Mosquito; *Megarhinus septentrionalis* D. & K.
1c Palpi of female one-quarter of the beak: 6
2a Wings spotted: 3
2b Wings not spotted: The Tree-Hole Anopheles; *Anopheles barberi* Coq.
3a Palpi dark brownish or black throughout: 4
3b Palpi with white marks at base of segments: 5
4a Wings with two white spots on the front margin of the wing; last

(hindmost) vein white with black ends: The Mottled Wing Anopheles; *Anopheles punctipennis* Say.

4b Wings with four distinct brown spots; last (hindmost) vein wholly dark brown: The Four-spotted Anopheles; *Anopheles quadrimaculatus* Say.

5a Wing with many dark spots but hindmost vein with three black spots: The Daylight Anopheles; *Anopheles crucians* Wied.

5b Wing with only four dark spots as in *Anopheles quadrimaculatus* Say.

Walker's Anopheles; *Anopheles walkeri* Theob.

6a Tarsi white- or yellowish-banded: 7

6b Tarsi uniform in color; not in any way marked or banded: 12

6c Tarsal segments narrowly banded at both ends; except on hind legs where joints between first and second and between second and third segments have broader white bands; distal tip of femora and tibiae white: The White-Lined Mosquito; *Orthopodomyia signifera* Coq.

7a Beak with black at each end and broadly pale yellow between; a small species: The Mottled Mosquito; *Psorophora discolor* Coq.

7b Beak with a more or less distinct white band or ring near its middle: 8

7c Beak without band or ring; uniform in color: 11

8a Abdomen with a distinct yellowish stripe down its dorsal aspect; sides of thorax white below a black edging: The White-Banded Salt Marsh Mosquito; *Aëdes sollicitans* Walk.

8b Abdomen without yellowish stripe; sides of thorax not white: 9

9a Black species; wing not heavily covered with scales: 10

9b A large brown species with a lighter band near tip of the posterior tibia; tibia not spotted; wings very heavily covered with scales: The Irritating Mosquito; *Mansonia perturbans* Walk.

10a A small blackish species with spotted markings on femur or tibia: Small Salt Marsh Mosquito; *Aëdes taeniorhynchus* Wied.

10b A large blackish species with a narrow white band near tip of femur; tibiae white-spotted: Spotted-Legged Mosquito; *Psorophora columbiae* D. & K.

11a Segments of the tarsi banded or ringed at base only:

(1) An extremely large, brownish black species, not showing a bluish tinge; the legs fringed with erect black scales: The Fringed-Legged Mosquito; *Psorophora ciliata* Fabr.

(2) A large species with very scaly wings; the sides of the thorax and the abdomen and tarsi banded with white: The Scaly-Winged Mosquito; *Aëdes grossbecki* D. & K.

(3) Wings thickly clothed with mixed yellow and brown scales; thorax with broad brown central stripe; first tarsal segment of anterior legs not banded: The Brown-Striped Woods Mosquito; *Aëdes excrucians* Walk.

(4) A small dark species with lightly scaled wings; the white bands of the feet narrow; the white bands running transversely

across the dorsal aspect of the abdomen almost divided at the center: The Swamp Mosquito; *Aëdes vexans* Meig. (was *sylvestris* Theob.)

(5) A good sized brown species with the banding yellowish rather than white; bands running transversely across dorsal aspect of abdomen, only a little, or not at all, notched at middle, claws of hind tarsi without tooth: The Brown Salt Marsh Mosquito; *Aëdes cantator* Coq.

(6) Very much like *Aëdes cantator;* bands of abdomen and feet broader and somewhat lighter in color; one tooth on each claw of hind tarsi (see Fig. II): The Brown Woods Mosquito; *Aëdes stimulans* Walk.

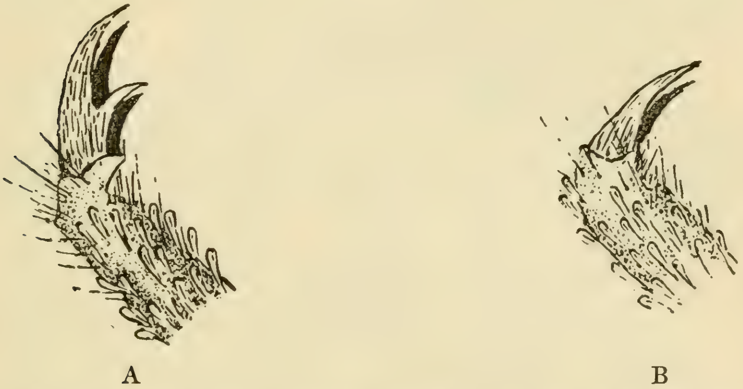

FIG. II. A shows hind tarsi of *Aëdes stimulans* and B shows hind tarsi of *Aëdes cantator.*

11b Segments of the hind tarsi, at least, white-banded or ringed at both base and tip; terminal segment of hind tarsi usually entirely white:

(1) A good sized brown species; thorax without lines or marks; bands on tarsal segments broad: The Woodland Pool Mosquito; *Aëdes canadensis* Theob.

(2) A small blackish species; tip of thorax covered with gray hairs; dark line down center of dorsal aspect of the thorax; bands on tarsi narrow and white: The Rock-Pool Mosquito; *Aëdes atropalpus* Coq.

(3) Medium sized species; easily recognized by the peculiar golden streaked appearance of thorax: Dyar's Mosquito, *Theobaldia morsitans* Coq.

11c Only the last tarsal segments of the hind legs white; a medium sized species, black with deep purple reflections: The Big Woods Mosquito; *Psorophora ferox* Humb.

12a Thorax marked in some way with stripes or spots, or the sides white or golden brown: 13

12b Thorax without marks or bands: 14

13a Species with longitudinal white or blue stripes:

(1) Moderate sized blackish species with two longitudinal white stripes on thorax: The Three-Striped Mosquito; *Aëdes trivittatus* Coq.

(2) Species with well defined broad central white band; top of head white: The Silver-Striped Mosquito; *Aëdes atlanticus* D. & K.

(3) Very small blackish species with a diffuse white central stripe: Dupree's Mosquito; *Aëdes dupreei* Coq.

(4) Small, dark brown species with a central stripe of metallic blue: The Sapphire-Lined Mosquito; *Uranotaenia sapphirina* O.S.

13b Species with thorax yellowish, white or brown; with a blackish central stripe or two, usually not sharply defined:

(1) Species with yellowish thorax; abdomen brownish with narrow white bands: The Brown-Striped Mosquito; *Aëdes sticticus* Theob.

(2) Species with thorax yellow; abdomen almost black, with broad white bands: The Red-Backed Mosquito; *Aëdes implacabilis* Walk.

(3) Species with dark brown thorax; with two yellowish spots in center; abdomen dark brown with whitish bands on apex of the segments: The Little Black Mosquito; *Culex apicalis* Adams

(4) Species with thorax golden brown; abdomen not banded; legs black: The Golden-Scaled Mosquito; *Aëdes aurifer* Coq.

(5) Species with thorax silvery white at sides not extending much on the back, most of which is black: The Tree-Hole Mosquito; *Aëdes triseriatus* Say

13c Species with thorax showing small white dots on each side of the middle and a "V"-shaped mark at base; abdomen banded: The White-Dotted Mosquito; *Culex territans* Walk.

13d Species with entire under-surface silvery, white or yellowish; small species with upper surface of body black and with an irregular stripe on thorax: The Pitcher Plant Mosquito; *Wyeomyia smithii* Coq.

14a Species with abdomen having either no bands or with only the merest indication of them; a uniformly dark brown species of moderate size: The Black-tailed Mosquito; *Theobaldia melanura* Coq.

14b Species with segments of abdomen narrowly banded at their bases:

(1) A small dark brown species with abdominal bands wider in the middle than at the sides, except on the seventh segment, on which the narrow band is of the same width throughout: The Little Smoky Mosquito; *Aëdes cinereus* Meig. (was *fuscus* O.S.)

(2) A moderate sized brown species with abdominal bands of

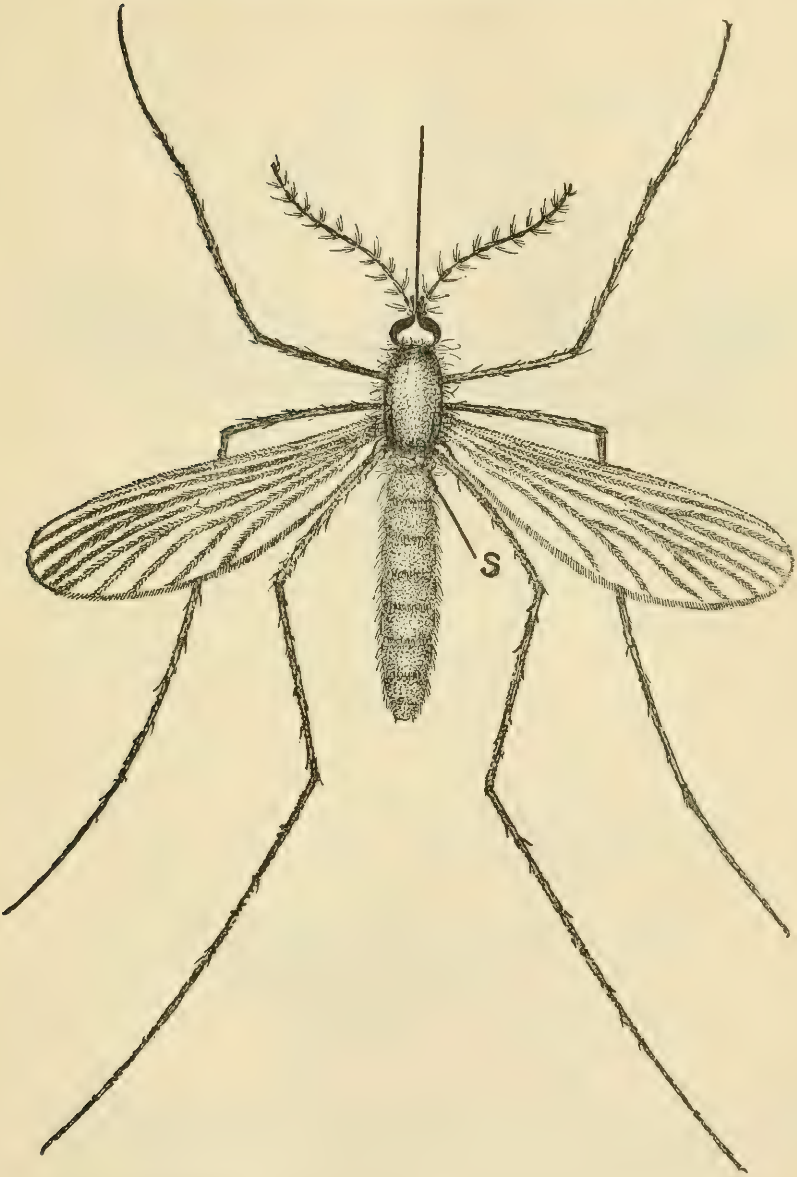

Fig. III. Adult of *Culex salinarius*. S shows the scutellum.

moderate width; hair covering of proboscis brown and pale beneath; darker toward the tip; scutellum with a tuft of golden brown bristles on each lobe (see Fig. III): The House or Rain Barrel Mosquito; *Culex pipiens* Linn.

(3) A slightly darker longer-legged species with abdominal bands narrower and always yellowish; hair-covering of beak

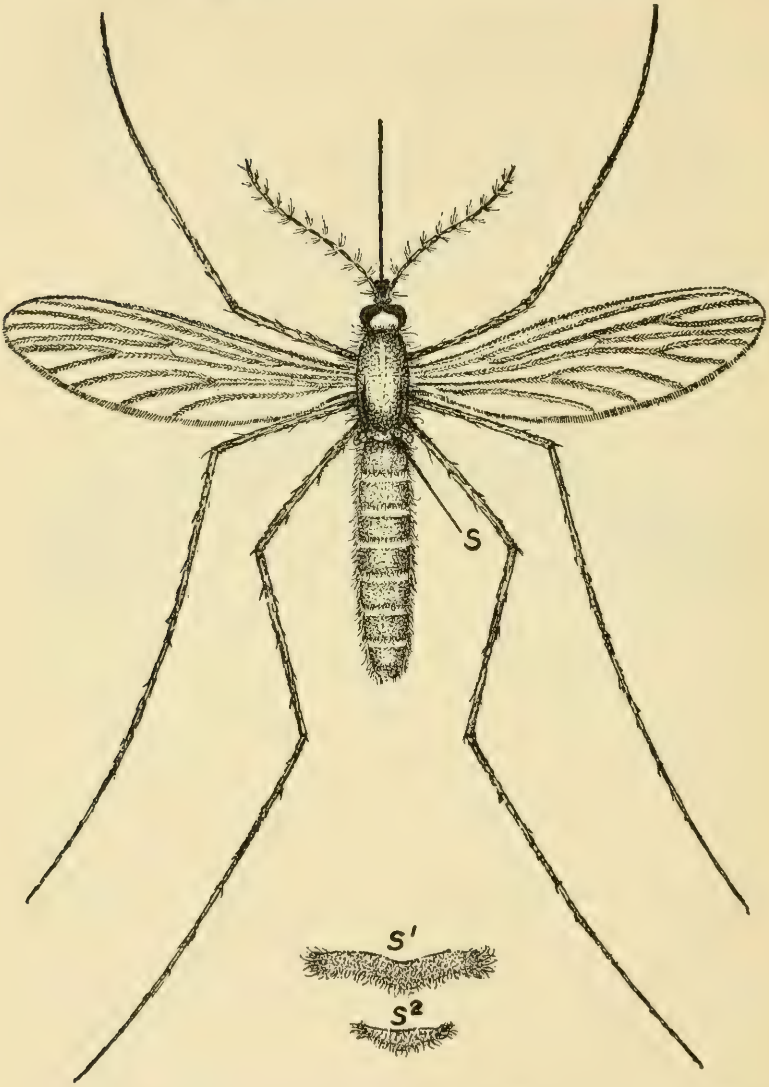

Fig. iv. Adult of *Culex pipiens.* S shows the scutellum on insect, and S^1 shows the scutellum greatly enlarged, and S^2 shows the scutellum enlarged.

brown but pale beneath; scutellum with a group of black bristles on each lobe (see Fig. IV): The Unbanded Salt Marsh Mosquito; *Culex salinarius* Coq.

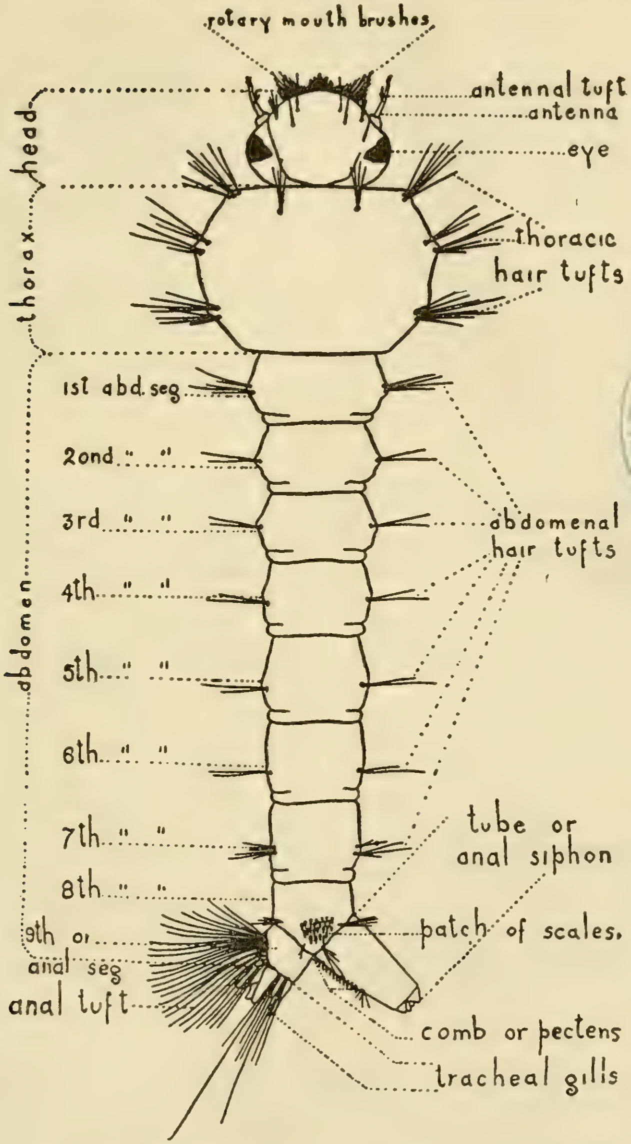
rotary mouth brushes
antennal tuft
antenna
eye
head
thorax
thoracic hair tufts
1st abd. seg.
2ond " "
3rd " "
4th " "
5th " "
6th " "
7th " "
8th " "
9th or anal seg
abdomen
abdomenal hair tufts
tube or anal siphon
patch of scales.
anal tuft
comb or pectens
tracheal gills

Fig. v. Larva of *Aëdes sollicitans.* (After John B. Smith.)

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KEY NUMBER 2

A Key to the Larvae of New Jersey Species of Mosquitoes

(FOR CHARACTERS, SEE FIG. V)

1a Siphon or breathing tube so short as to seem absent; larvae lie parallel with surface of water (see Fig. VI, E):

1b Siphon or breathing tube distinctly present (see Fig. VII): 6

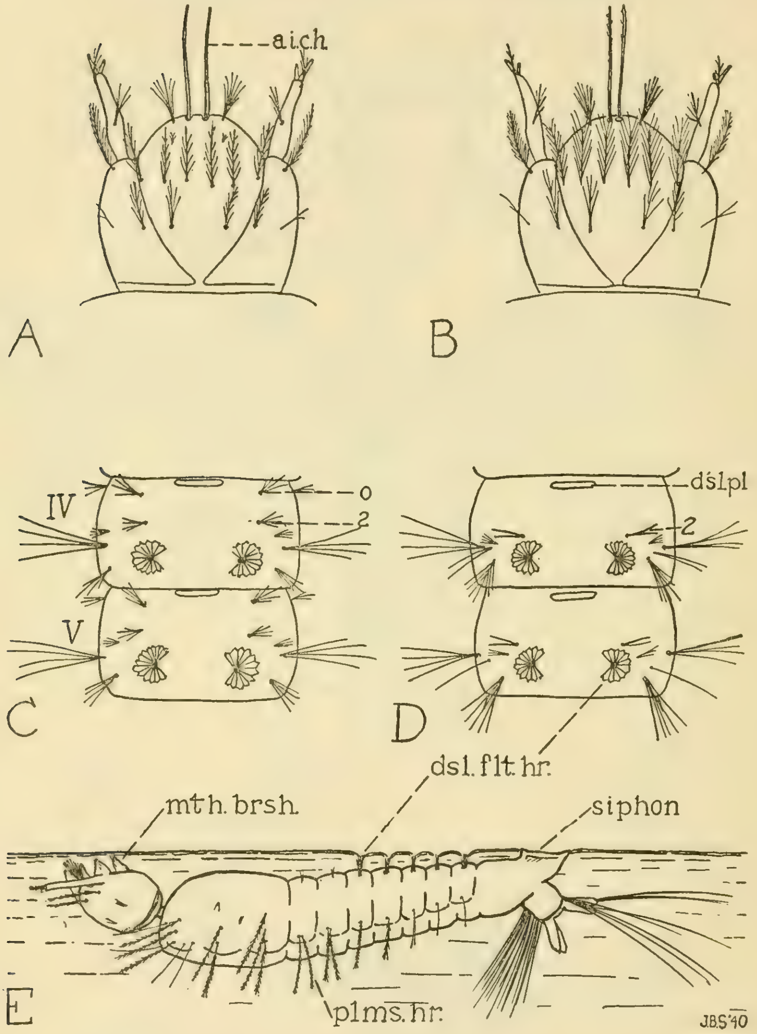

Fig. vi. *Anopheles* species, details of larvae. A. Head of *Anopheles quadrimaculatus* Say. B. Head of *Anopheles walkeri* Theobald. C. Fourth and fifth abdominal segments of *Anopheles crucians Wiedman.* D. Fourth and fifth abdominal segments of *Anopheles punctipennis* Say. E. *Anopheles* larva, showing position when feeding. *a.i.c.h.*: anterior internal clypeal hairs; *dsl. flt. hr.*: dorsal float hairs; *dsl. pl.*: dorsal plate; *mth. brsh.*: mouth brush; *plms. hr.*: plumose hair.

2a Abdomen with plumose (plume-like) lateral hairs on the first six segments; hairs of head simple: *Anopheles barberi* Coq.

2b Abdomen with plumose lateral hairs on first three segments only; hairs of head plumose (see Fig. VI, E): 3

3a Abdominal segments 4 and 5 with two conspicuous tufted hairs (hairs 2 and 0) anterior to palmate hair: *Anopheles crucians* Wied. (see Fig. VI, C).

3b Abdominal segments 4 and 5 with but one conspicuous hair (the antepalmate hair or hair 2) anterior to palmate hair (see Fig. VI, D): 4

4a Anterior internal clypeal hairs well separated at base (see Fig. VI, A): *Anopheles quadrimaculatus* Say.

4b Anterior internal clypeal hairs close together at base (see Fig. VI, B): 5

5a Anterior internal clypeal hairs with minute branches on outer half (see Fig. VI, B): *Anopheles walkeri* Theob.

5b Anterior internal clypeal hairs without minute branches on outer half: *Anopheles punctipennis* Say

6a Head (in last stage) elongate elliptical: *Uranotaenia sapphirina* O.S.

6b Head rounded or transverse, not elongate: 7

7a Anal segment with a ventral brush (see Fig. VII): 8

7b Anal segment without a ventral brush; never more than ten hairs in its place: *Wyeomyia smithii* Coq.

8a Air-tube without pecten (two rows of spines on posterior edge at base): 9

8b Air-tube with pecten (see Fig. VII): 10

9a Air-tube truncated, with a saw-toothed projection: *Mansonia perturbans* Walk.

9b Air-tube normal, not so modified: *Orthropodomyia signifera* Coq.

9c Air-tube stout, conically tapered outwardly, about two and one-half times as long as wide: *Megarhinus septentrionalis* D. & K.

10a A single paired hair-tuft on air-tube [rarely with additional hairs (see Fig. VII)]: 16

10b Air-tube with several tufts (if lacking, air-tube is much elongated): 11

11a Anal segment with hair tufts along the lateral edge preceding the posterior brush; the scales of the eighth abdominal segment forming a triangular patch, incomplete at the base of the air-tube: *Theobaldia morsitans* Coq.

11b Anal segment with hair tufts in posterior brush only: 12

12a The scales of the eighth abdominal segments replaced by a single straight row of chitinous bars; a row of twelve hair tufts along the posterior edge of the air-tube, extending from a point before the middle to a short distance from the tip; the hairs on the anterior edge of the prothorax extending beyond the antennae: *Theobaldia melanurus* Coq.

12b The scales of the eighth abdominal segment distinct and separate: 13

13a Antennae with the tuft (see Fig. VII) at the middle; a pair of long hairs at the middle of the anterior-lateral edge of the air tube: *Culex territans* Walk. (was *restuans* Theob.).

13b Antennae with tuft well beyond the middle: 14

14a Air-tube with four paired, evenly spaced tufts, in line; both pairs of dorsal head-hairs single: *Culex apicalis* Adams (was *territans* Walk.)

14b Air-tube with four (sometimes more) paired tufts, the next-to-last tuft moved out of line; dorsal head hairs multiple: 15

15a Air-tube six or more times as long as wide, the sides straight, with little or no tapering; anal gills small, tapered, not as long as the anal segment: *Culex salinarius* Coq.

15b Air-tube less than six times as long as wide, the sides curved, tapering rather rapidly after the middle; gills rather broad, tips bluntly pointed, longer than the anal segment: *Culex pipiens* Linn.

16a Mouth brushes fitted for holding, or air-tube or antennae very much inflated: 17

16b Without these peculiar modifications: 20

17a Antennae very large, swollen towards the tip: *Psorophora discolor* Coq.

17b Antennae cylindrical, not swollen: 18

18a Antennae about one-third as long as the head: *Psorophora ciliata* Fabr.

18b Antennae as long as or longer than the head: 19

19a Dorsal head hairs multiple; pecten on air-tube of five hairs; a two-haired tuft at the outer third: *Psorophora columbiae* D. & K.

19b Dorsal head-hairs double; air tube with a small pecten of few teeth; hair tuft lacking: *Psorophora ferox* Humb.

20a Anal segment ringed by the dorsal plate (see Fig. VII): 21

20b Anal segment not ringed by the dorsal plate, *i.e.*, plate chitinization interrupted on ventral line more or less broadly: 26

21a Air-tube moderate, about three times as long as wide: 22

21b Air-tube short, less than three times as long as wide: 23

22a Anal gills extremely long and tracheate: *Aëdes dupreei* Coq.

22b Anal gills less than twice as long as the anal segments: *Aëdes implacabilis* Walk.

23a Comb of eighth segment of about six scales: *Aëdes atlanticus* D. & K.

Fig. vii. *Aëdes sollicitans* Walker. A. Antenna. B. Antennal hair tuft. C. Head hairs. D. Hair tufts. E. Ventral brush or anal tuft. F. Anal gills or tracheal gills. G. Siphon or breathing tube. H. Patch of scales. I. Pecten, pecten spines or siphonal spines. J. Hair tufts of air tube or siphonal hair tuft. Fig. viii. *Aëdes vexans* Meigen. A. Antenna. B. Antennal hair tuft. C. Head hairs. D. Hair tufts. E. Ventral brush or anal tuft. F. Anal gills or tracheal gills. G. Siphon or breathing tube. H. Patch of scales. I. Pecten, pecten spines or siphonal spines. Fig. ix. *Culex territans* Walker. A. Antenna. B. Antennal hair tuft. C. Head hairs. D. Hair tufts. E. Ventral brush or anal tuft. F. Anal gills or tracheal gills. G. Siphon or breathing tube. H. Patch of scales. I. Pecten, pecten spines or siphonal spines. (All drawn from Howard, Dyar & Knab.)

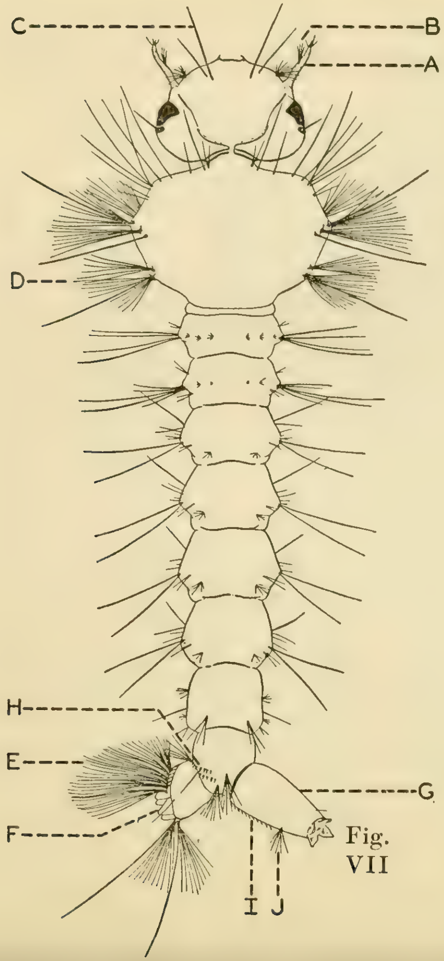
C
B
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Fig. VII

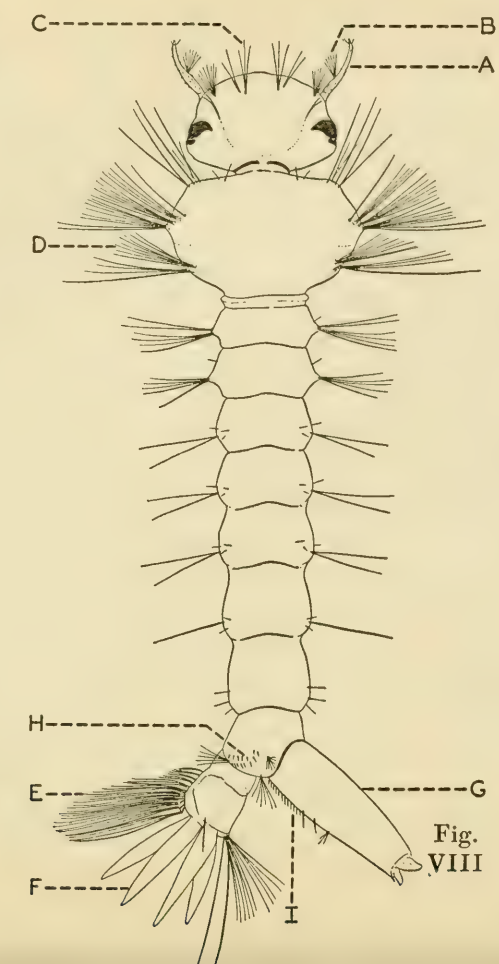


Fig. VIII

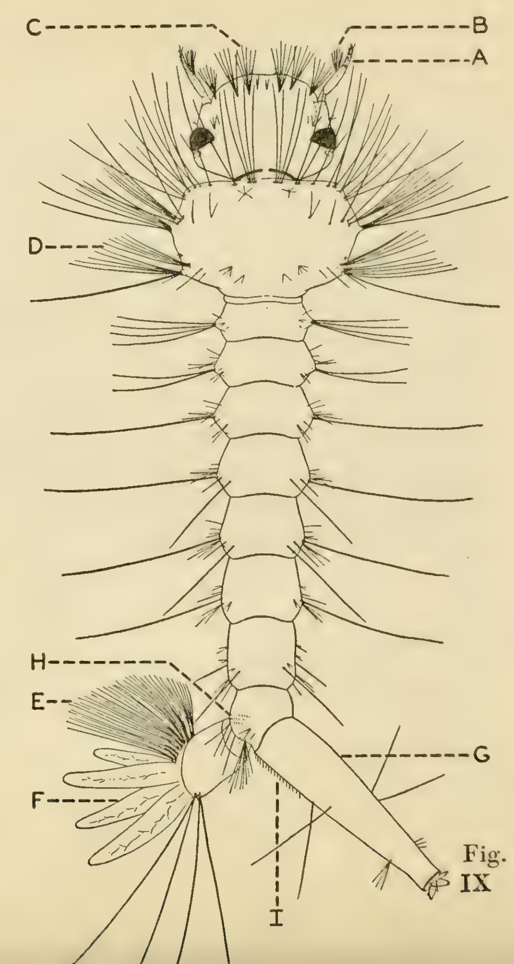


Fig. IX

23b Comb of eighth segment of many scales in a triangular patch: 24

24a Anal gills as long as or longer than the anal segments: *Aëdes trivittatus* Coq.

24b Anal gills shorter than the anal segment; bud-like or almost vestigial: 25

25a Lateral abdominal hairs double on segments three to six: *Aëdes sollicitans* Walk.

25b Lateral abdominal hairs triple on segments three to five, single on six: *Aëdes taeniorhynchus* Wied.

26a Air-tube with tuft within the pecten; anal gills three times as long as anal segment: *Aëdes atropalpus* Coq.

26b Air-tube with the tufts beyond the pecten: 27

27a Pecten of the air-tube with outer teeth unevenly spaced: 28

27b Pecten of the air-tube with evenly spaced teeth: 31

28a Air-tube elongate; comb a patch of scales three rows deep, and gills about as long as the anal segment: *Aëdes excrucians* Walk.

28b Air-tube less elongate; about three times as long as wide: 29

29a Antennae large, enlarged basally; tuft rather beyond the middle: *Aëdes aurifer* Coq.

29b Antennae moderate only; tuft before the middle: 30

30a Lateral abdominal hairs double on third to fifth segments; with from ten to fifteen scales in comb on eighth segment, arranged in an irregular double row; last three or four spines of pecten larger than others: *Aëdes vexans* Meig. (was *sylvestris* Theob.).

30b Lateral abdominal hairs single beyond second segment; air-tube slender; twelve scales on eighth segment in an irregular single row; spines of pecten equal in length: *Aëdes cinereus* Meig. (was *fuscus* O.S.).

31a Anal gills at least twice as long as the anal segment: 32

31b Anal gills about as long as, or shorter than the anal segment: 33

32a Anal gills three times as long as the anal segment, full, rounded; antenna with a single hair at middle: *Aëdes triseriatus* Say

32b Anal gills twice as long as anal segment, pointed; a multiple-haired tuft at middle of antennal joint: *Aëdes sticticus* Meig.

33a Anal gills very short, but pointed; air-tube two and one-half times as long as wide; pecten not reaching the middle, followed by a six-haired tuft: *Aëdes cantator* Coq.

33b Anal gills about as long as the anal segment: 34

34a Lower head hairs in tufts of three or more; a small crescent-shaped mark on dorsal surface of head: *Aëdes canadensis* Theob.

34b Lower head hairs single or double; dorsal surface of head showing no such markings: 35

35a Lateral spinules of comb-scales as long as apical one; comb-scales of eighth segment elongate; fourth instar larvae about one millimeter long: *Aëdes grossbecki* D. & K.

35b Lateral spinules of comb-scales shorter than apical one; scales rather broad; fourth instar larvae about 8/10 mm. long: *Aëdes stimulans* Walk.

KEY NUMBER 3

Eye and Hand-lens Key to the Adults of the More Common Species *

A Palpi at least three-fourths the length of the beak.

I Wing mottled, bearing one large rather distinct white spot: *Anopheles punctipennis* Say

II Wing without white spot but with four fairly distinct blackish spots; the spots due to aggregation of scales: palpi dark brown throughout: *Anopheles quadrimaculatus* Say

III Same as II except palpi show white at base of segment and at top: *Anopheles walkeri* Theob.

IV Wing not as above but with decidedly blackish front edge; this appearance due to aggregation of scales along front edge; *Anopheles crucians* Wied.

B Palpi scarcely more than one-fourth the length of the beak.

I Feet without white or yellowish bands:

1 Front edge of abdominal segments bordered by white bands: *Culex pipiens* Linn., *Culex salinarius* Coq.

2 Back edge of abdominal segments bordered by white bands which are narrow and sometimes broken: *Culex apicalis* Adams

II Feet white or yellowish banded:

1 Beak with white circular band:

a Edges of white band not sharp; rough scaly species, much white on legs and feet: *Mansonia perturbans* Walk.

b Edges of white band sharp:

(1) Yellowish-white band running lengthwise the upper surface of the abdomen; no white bands or sharply-defined spots on the hind femur or tibia: *Aëdes sollicitans* Walk.

(2) No lengthwise median band; no spots on the hind femur or tibia; two white spots, one on each side of the dorsal aspect of each of two abdominal segments before last: *Aëdes taeniorhynchus* Wied.

2 Beak without circular band:

a Abdominal bands white and rather sharp edged; abdominal bands so strongly notched from the rear as to appear almost divided; tarsal bands not occurring on both ends of the same segment: *Aëdes vexans* Meig.

b Abdominal bands not so notched; white bands on both ends of the hind tarsal segments, the joint between the tibia and the first tarsal segment being completely white and thus forming the characteristic "white knees" of this species: *Aëdes canadensis* Theob.

c Abdominal and tarsal bands yellowish, no sharp notch-

---

* It is impracticable to separate certain species such as *C. pipiens* and *C. salinarius* and *A. cantator* and *A. stimulans* by hand-lens characters. For such work see Key 1.

ing in former, tarsal bands on basal ends of segments only: *Aëdes cantator* Coq., *Aëdes stimulans* Walk., *Aëdes excrucians* Walk.

III Very large; twice as long from head to tail as any other common species; legs conspicuously fringed with long hairs: *Psorophora ciliata* Fabr.

KEY NUMBER 4

Eye and Hand-lens Key to the Larvae of the More Common Species

A Siphon or breathing tube so very short as to seem absent; larvae lie parallel with the surface of the water: *Anopheles punctipennis* Say, *Anopheles quadrimaculatus* Say, *Anopheles walkeri* Theob., *Anopheles crucians* Wied.

B Siphon or breathing tube distinctly present:

- I Antennae arising from near middle of sides of the head. Very large species: *Psorophora ciliata* Fabr.
- II Antennae arising from sides of anterior of head:
  - 1 Breathing tube sharp-pointed, spike-like: *Mansonia perturbans* Walk.
  - 2 Breathing tube normal with a blunt end:
    - a Found in fresh water; breathing tube medium length, two and one-half or three times as long as broad; head with two or three small colored patches, all in front of base of antennae: *Aëdes vexans* Meig.
    - b Found in fresh water; breathing tube three and one-half times as long as broad; antennal tuft near the middle; head without colored patches: *Aëdes stimulans* Walk.
    - c Found in fresh water, woodland pools; breathing tube three times as long as broad; head with three colored patches, all back of base of antennae: *Aëdes canadensis* Theob.
    - d Found in fresh water; breathing tube four times as long as broad, slightly swollen at base: *Culex pipiens* Linn.
    - e Found in brackish water; breathing tube fully five times as long as broad, tapering evenly from base to tip: *Culex salinarius* Coq.
    - f Found in fresh water; breathing tube about eight times as long as broad, slightly constricted at middle: *Culex apicalis* Adams
    - g Found in fresh water; breathing tube about three and one-half times as long as broad; antennal tuft decidedly before the middle; head with one larger and several small colored patches: *Aëdes excrucians* Walk.
    - h Found in salt or brackish water; breathing tube hardly

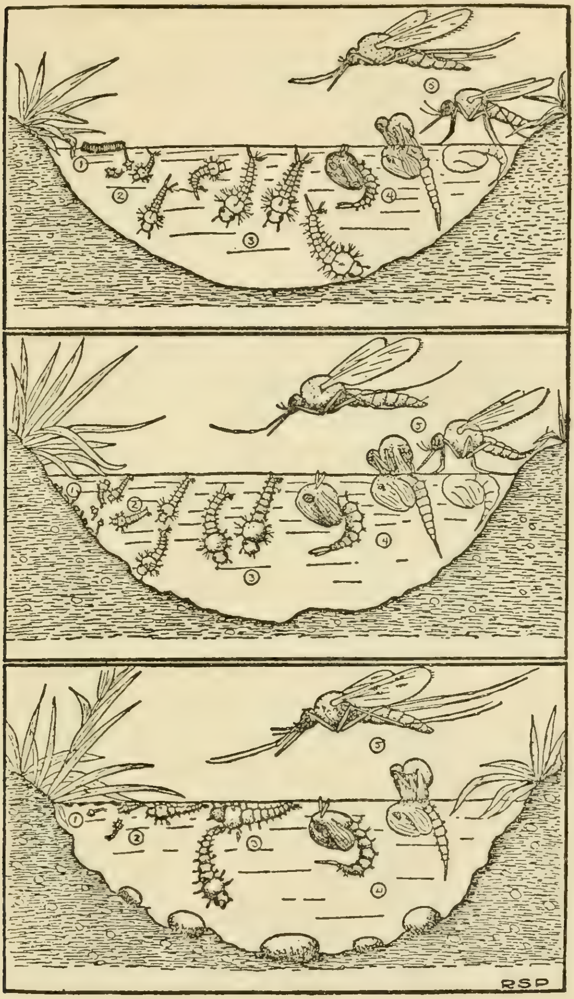


FIG. x. Diagrammatic life history of three typical species. TOP. House mosquito. CENTER. Salt-marsh or woodland pool or fresh-water swamp mosquito. BOTTOM. Malarial mosquito. KEY TO NUMBERS: 1, eggs; 2, hatching larvae; 3, grown larvae or wrigglers; 4, pupae; 5, adults emerging and flying away. In larvae and pupae note breathing tubes at surface of water.

twice as long as broad; head width hardly more than one-half width of thorax: *Aëdes sollicitans* Walk.

i Found in salt or brackish water; breathing tube about one and one-half times as long as broad; head about two-thirds width of thorax: *Aëdes taeniorhynchus* Wied.

j Found in salt or brackish water; breathing tube a little less than three times as long as broad; head globular about one-half width of thorax: *Aëdes cantator* Coq.

3

THE NEW JERSEY MOSQUITO FAUNA

Counting two species of *Corethra,* Dr. Smith lists thirty-seven species of mosquitoes in his Report in 1904 (23). In his "Insects of New Jersey" (27), Dr. Smith lists forty species for the state, not including any members of the genus *Corethra.* In New Jersey Experiment Station Bulletin 348 (10) the writer listed a total of thirty-nine species, of which two were considered as aberrant forms of other species, or actually a total of thirty-seven species. In this book the writer includes descriptions of thirty-seven reasonably distinct species of the family *Culicidae.*

It is important to know not only what species occur in the state but the numbers representing each species and their geographical and seasonal distribution. Owing to the limitations of hand collections, however, it was not until recently that a sufficient number of mosquitoes had been collected to give an adequate idea of numbers and distribution.

By 1932 a mechanical trap or gauge had been developed which collected enough mosquitoes to serve this purpose. In 1932 this trap consisted of a nine-inch diameter tube of galvanized steel, thirty inches long. In the front end was fitted a small electric motor carrying an eight-inch fan. Over the front end of the tube was placed a quarter-inch hail screen cap to keep out large insects. Within the tube and back of the fan was placed an eccentric cone of wire mosquito net. The open end of this cone just nicely fitted into the inside of the tube. When in position the cone lay with the straight side along the barrel of the trap, and the diagonal side crossed the tube to the straight side. The tip of the cone was pierced by a half inch hole which led directly into a pint fruit jar, which was screwed into a cap soldered to the outside of the trap. The whole trap was mounted horizontally on a ball-bearing turn table, and a metal fin, located along the upper face of the barrel, served to keep the front of the trap facing the wind.

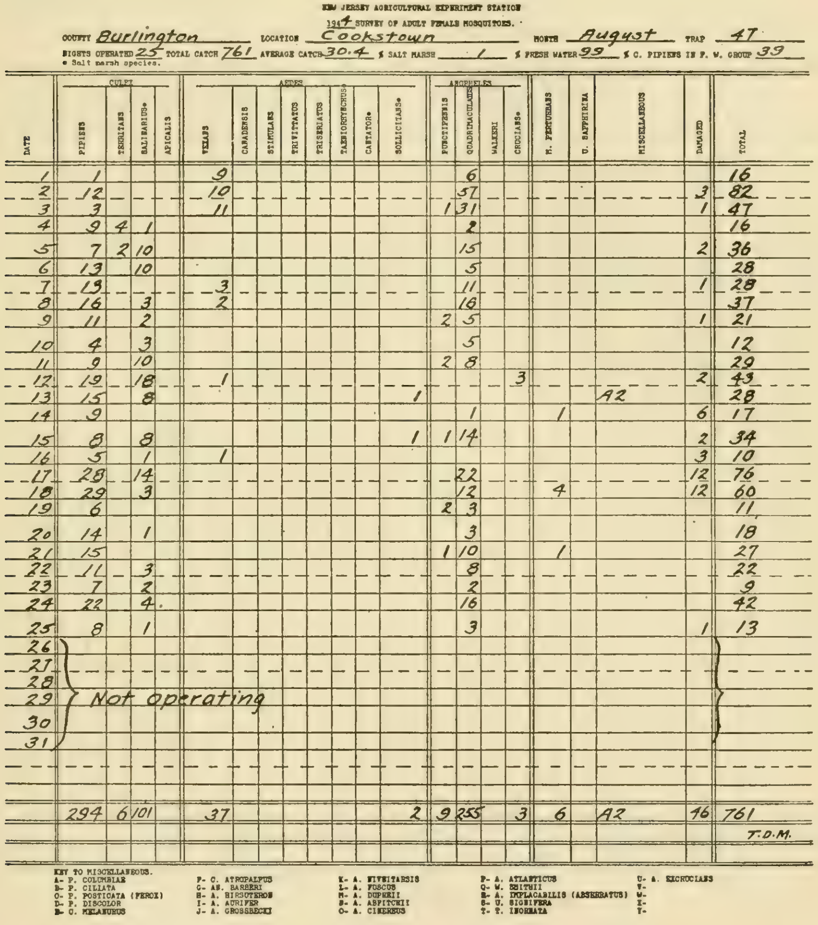
By clock work this trap was thrown into operation in the evening and out of operation in the morning. When in operation the mosquitoes were attracted by the twenty-five-watt frosted white light bulb. When

TABLE I

Total number of female mosquitoes taken in New Jersey traps during the 10-year period from 1932 to 1941, inclusive. Traps are arranged in order of general latitude, starting at the northern corner of the State. Species are arranged in order of numerical predominance.

Place	Aëdes sollicitans	Culex pipiens	Aëdes vexans	An. crucians	Mansonia perturbans	An. walkeri	An. quadrimaculatus	Aëdes taeniorhynchus	Aëdes cantator	Aëdes stimulans	Aëdes trivittatus	Culex apicalis	An. punctipennis	Uran. sapphirina	Culex salinarius	Theobaldia melanurus	Aëdes canadensis	Aëdes triseriatus	Psorophora columbiae	Culex territans	Psorophora ciliata	Aëdes hirsuteron	Aëdes atropalpus	Aëdes cinereus	Orthopod signifer	Aëdes excrucians	Psorophora ferox	An. barberi	Wyeomyia smithii	Aëdes grossbecki	Aëdes aurifer	Totals	Place
Franklin	28	1,261	3,041	11	53	2	52	—	59	3	46	30	218	7	—	1	14	3	—	—	5	3	—	—	—	—	—	—	—	—	—	4,810	Franklin
Newton	11	1,386	2,051	1	52	1	61	1	11	5	29	33	217	7	1	—	3	7	—	—	7	—	—	—	—	—	—	—	—	—	—	3,884	Newton
Denville (1937–41)	4	1,050	1,984	—	68	15	22	—	13	275	74	32	68	91	—	39	9	4	26	1	1	3	—	—	—	—	1	—	—	—	—	3,780	Denville (1937–41)
Dover (1937–41)	2	1,466	1,876	—	28	—	22	—	1	52	3	33	82	29	—	22	7	—	5	5	—	—	—	—	—	—	—	—	—	—	—	3,633	Dover (1937–41)
Rockaway (1937–41)	2	1,412	1,764	—	61	6	54	—	14	56	8	34	74	56	—	8	3	10	3	2	—	—	—	—	1	—	—	2	—	—	—	3,570	Rockaway (1937–41)
Morris Plains (1937–41)	6	541	5,940	1	207	4	66	—	19	96	1	25	71	41	—	14	—	—	22	1	1	—	—	—	—	—	—	—	—	—	—	7,056	Morris Plains (1937–41)
Boonton (1937–41)	3	1,813	4,543	—	526	2	24	—	4	285	11	77	95	86	—	19	7	15	4	1	—	—	—	—	—	—	—	—	—	—	—	7,515	Boonton (1937–41)
Morristown (1937–41)	2	1,101	10,269	2	83	8	13	15	—	126	33	28	70	93	—	42	2	11	7	5	4	—	—	—	1	—	—	—	—	—	—	11,915	Morristown (1937–41)
Mountain Lakes (1937–41)	7	913	1,270	—	1,071	11	34	—	3	77	13	25	22	34	—	12	6	4	2	1	1	—	—	—	3	—	—	—	—	—	—	3,509	Mountain Lakes (1937–41)
Chatham & Madison	414	5,656	28,672	10	462	8	86	1	217	118	68	89	113	276	3	136	81	16	2	6	—	26	—	—	1	—	—	—	—	—	—	36,411	Chatham & Madison
Pine Brook (1938–41)	45	12,695	49,882	—	3,403	9,997	2,222	—	40	1,989	259	302	52	210	—	491	10	6	223	6	18	1	—	—	—	—	11	—	—	—	—	81,862	Pine Brook (1938–41)
Livingston (1938–41)	6	1,670	35,677	—	38	27	604	—	312	565	2,860	72	166	44	—	62	1	493	57	2	1	—	—	—	—	—	—	—	—	—	—	42,657	Livingston (1938–41)
Totowa	96	5,268	3,083	20	123	—	34	2	33	38	18	40	138	7	12	—	14	1	1	2	5	—	—	—	2	—	—	1	1	—	—	8,939	Totowa
Paterson	84	4,169	1,886	4	52	—	4	2	90	10	2	24	12	—	—	—	—	1	1	—	1	—	—	—	—	—	—	1	1	—	—	6,344	Paterson
Ridgefield Park	415	12,577	3,179	15	141	—	3	5	135	30	—	158	20	4	35	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	16,718	Ridgefield Park
E. Rutherford	682	10,677	5,637	37	110	—	3	5	306	42	2	176	18	9	212	1	19	3	—	—	—	—	—	—	2	—	—	1	—	—		17,942	E. Rutherford
E. Paterson (1932–36) Hackensack (1937–41)	126	7,045	1,386	5	30	—	4	—	40	3	1	20	10	7	1	—	2	—	1	—	—		—		1	—	—		—	—		8,682	E. Paterson (1932–36) Hackensack (1937–41)
Secaucus	1,969	55,039	7,497	16	483	—	1	43	389	25	2	332	22	16	398	—	38	1	—	—	1	—	—	—	—	—	—	—	—	—	—	66,272	Secaucus
Jersey City	375	2,470	829	6	74	—	—	—	15	1	2	12	1	18	26	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	3,831	Jersey City
Bayonne	941	6,284	1,001	71	26	—	1	6	31	6	—	35	2	6	25	1	3	—	1	—	1	—	—	—	—	—	—	—	—	—	—	8,441	Bayonne
Kearny	900	5,234	2,644	—	51	—	1	3	191	6	—	58	3	9	17	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9,120	Kearny
Port Newark	1,827	5,130	2,410	7	52	—	1	—	46	7	—	38	—	4	241	—	160	—	8	—	—	—	—	—	—	—	—	—	—	—	—	9,931	Port Newark
Belleville (except 1939)	371	5,638	6,044	9	11	—	1	1	102	6	2	166	9	16	4	—	5	1	—	—	1	—	—	—	1	—	—	—	—	—	—	12,388	Belleville (except 1939)
Essex Fells (1932–36) W. Caldwell (1937–41)	139	3,070	13,925	17	697	80	103	16	168	12	30	64	66	94	1	—	21	18	—	1	8	—	—	—	—	—	—	—	—	—	—	18,530	Essex Fells (1932–36) W. Caldwell (1937–41)
Springfield	104	3,149	15,092	10	65	—	12	1	95	2	20	48	229	13	17	—	6	6	—	2	—	—	—	—	2	—	—	—	1	—	—	18,874	Springfield
Elizabethport (1932–35) Elizabeth (1936–41)	894	4,081	3,312	13	21	—	2	10	53	7	1	26	13	13	18	—	10	—	6	—	—	—	—	—	1	—	—	—	—	—	—	8,481	Elizabethport (1932–35) Elizabeth (1936–41)
New Providence Boro (1937–41)	16	3,936	8,967	21	755	13	121	—	63	32	150	72	256	70	61	431	157	22	77	89	14	87	113	24	—	22	2	—	—	1	—	15,572	New Providence Boro (1937–41)
Woodbridge	3,608	7,392	4,308	64	463	—	1	27	125	25	—	90	43	12	27	—	18	3	2	3	24	—	—	—	1	—	—	2	—	—	—	16,238	Woodbridge
New Brunswick	388	4,985	3,008	14	414	—	5	3	303	16	1	37	53	2	19	—	3	4	11	2	7	1	—	—	19	—	—	—	—	—	1	9,296	New Brunswick
Dayton	68	6,010	3,492	30	6,790	—	16	5	8	43	16	192	67	4	4	6	442	3	2	1	12	—	—	1	—	—	6	6	1	—	—	17,225	Dayton
South Amboy	4,894	5,646	2,503	139	1,884	—	86	65	427	117	7	34	48	41	7	—	5	3	14	—	4	—	—	—	—	—	—	—	—	—	—	15,924	South Amboy
W. Keansburg	3,936	7,116	4,527	339	290	1	32	77	251	11	7	48	68	47	75	—	92	4	3	294	1	—	—	—	1	—	—	—	—	—	—	17,220	W. Keansburg
Monmouth Beach (1932–40) Ft. Monmouth (1941)	4,395	5,084	794	102	11	—	2	63	21	—	—	12	11	19	13	—	1	1	—	139	—	—	—	—	—	—	—	—	—	—	—	10,668	Monmouth Beach (1932–40) Ft. Monmouth (1941)
Bay Head	2,014	1,667	201	146	35	—	1	11	36	1	—	41	—	—	21	—	—	1	—	—	—	—	—		—	—	—	—		—		4,775	Bay Head
Seaside Park	8,281	1,855	1,357	45	5	—	—	474	135	4	1	24	—	1	9	—	6	2	4	—	—	—	—	—	—	—	—	—	—	—	—	12,203	Seaside Park
Barnegat	27,920	17,265	1,986	451	71	—	—	848	203	8	1	36	23	1	19	—	32	11	1	1	4	—	—	—	—	—	—	—	—	—	—	48,881	Barnegat
Beach Haven	9,054	2,623	1,268	153	28	—	2	479	12	—	—	10	—	—	3	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13,633	Beach Haven
Tuckerton	26,043	22,231	4,839	349	527	2	1,112	2,044	72	4	4	163	7	19	286	2	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	57,716	Tuckerton
Absecon	24,479	1,898	990	250	24	—	1	388	43	1	—	8	5	9	3	—	4	6	4	—	1	—	—	—	—	—	—	—	1	—	—	28,115	Absecon
Brigantine	5,542	270	474	26	4	—	1	123	5	—	—	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6,454	Brigantine
Somers Point (1932–36) Linwood (1937–41)	16,193	4,116	807	365	15	1	66	253	19	1	1	59	5	19	10	—	—	—	7	—	—	—	—	—	—	—	—	—	—	—	—	21,923	Somers Point (1932–36) Linwood (1937–41)
Longport (1937–40) Margate (1941)	9,031	2,684	926	31	89	—	3	70	—	1	—	1	1	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	12,839	Longport (1937–40) Margate (1941)
Ocean City	9,822	5,899	1,288	229	21	1	24	169	95	—	—	23	6	1	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	17,581	Ocean City
Sea Isle City	9,567	1,848	1,631	270	33	—	10	121	68	1	7	8	—	—	3	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	13,569	Sea Isle City
Cape May	8,983	5,830	1,872	465	1,833	18	145	198	179	3	—	62	6	—	18	—	6	1	75	—	1	—	—	—	—	—	—	—	2	—	—	19,686	Cape May
Dennisville	26,676	18,363	2,166	17,451	1,195	—	200	843	268	6	—	200	40	13	58	—	11	—	—	—	2	—	—	—	24	—	—	—	—	—	—	67,522	Dennisville
Cedarville	127,274	15,442	3,646	4,390	174	—	607	1,256	285	14	—	138	11	1	13	—	4	—	11	—	2	—	—	—	—	—	—	—	—	—	—	153,268	Cedarville
Salem	4,910	11,723	16,937	1,038	98	39	1,865	66	128	8	2	73	47	25	51	—	—	1	23	—	172	—	—	—	—	—	—	—	—	—	—	37,206	Salem
Delair (1937–41)	88	8,363	3,460	94	994	18	157	7	84	9	1	77	186	385	11	—	5	—	2	—	—	—	—	72	1	—	—	—	—	—	—	14,014	Delair (1937–41)
Totals	343,235	323,041	286,314	26,717	23,730	10,254	7,893	7,701	5,217	4,147	3,683	3,394	2,674	1,850	1,724	1,287	1,173	665	606	565	301	121	113	97	61	23	20	13	7	1	1	1,056,628	Totals

they flew within six inches or less of the trap they were sucked in and washed down the cone of screen wire into the fruit jar which, of course, was equipped to act as a cyanide bottle.



NEW JERSEY AGRICULTURAL EXPERIMENT STATION
1934 SURVEY OF ADULT FEMALE MOSQUITOES.

COUNTY Burlington LOCATION Cookstown MONTH August TRAP 47
NIGHTS OPERATED 25 TOTAL CATCH 761 AVERAGE CATCH 30.4 % SALT MARSH 1 % FRESH WATER 99 % C. PIPIENS IN F. W. GROUP 39
* Salt marsh species.

	CULEX				AEDES								ANOPHELES								
DATE	PIPIENS	TERRITANS	SALINARIUS*	APICALIS	VEXANS	CANADENSIS	STIMULANS	TRIVITTATUS	TRISERIATUS	TAENIORHYNCHUS*	CANTATOR*	SOLLICITANS*	PUNCTIPENNIS	QUADRIMACULATUS	WALKERI	CRUCIANS*	M. PERTURBANS	U. SAPPHIRINA	MISCELLANEOUS	DAMAGED	TOTAL
1	1				9									6							16
2	12				10									57						3	82
3	3				11								1	31						1	47
4	9	4	1											2							16
5	7	2	10											15						2	36
6	13		10											5							28
7	13				3									11						1	28
8	16		3		2									16							37
9	11		2										2	5						1	21
10	4		3											5							12
11	9		10										2	8							29
12	19		18		1											3				2	43
13	15		8									1							A2		28
14	9													1			1			6	17
15	8		8									1	1	14						2	34
16	5		1		1															3	10
17	28		14											22						12	76
18	29		3											12			4			12	60
19	6												2	3							11
20	14		1											3							18
21	15												1	10			1				27
22	11		3											8							22
23	7		2											2							9
24	22		4											16							42
25	8		1											3						1	13
26																					
27																					
28																					
29	Not operating																				
30																					
31																					
	294	6	101		37							2	9	255		3	6		A2	46	761
																					T.D.M.

KEY TO MISCELLANEOUS.
A- P. COLUMBIAE
B- P. CILIATA
C- P. POSTICATA (FEROX)
D- P. DISCOLOR
E- C. MELANURUS
F- C. ATROPALPUS
G- AE. BARBERI
H- A. HIRSUTEROR
I- A. AURIFER
J- A. GROSSBECKI
K- A. NIVEITARSIS
L- A. FUSCUS
M- A. DUPREII
N- A. ABFITCHII
O- A. CINEREUS
P- A. ATLANTICUS
Q- W. SMITHII
R- A. IMPLACABILIS (ABSERRATUS)
S- U. SIGNIFERA
T- T. INORNATA
U- A. EXCRUCIANS
V-
W-
X-
Y-

FIG. XI. Record of one month's catch of female mosquitoes taken in N. J. mosquito trap.

By 1933 the type of trap was changed, and the cost of construction reduced. The tube was suspended vertically under a conical cap of twice the diameter of the barrel. The light bulb was mounted immediately under the large conical cap. The screen wire cover was made to deliver at the bottom of the barrel instead of at the side. The whole trap was suspended vertically from a one-armed standard by a fitting in the apex of the conical cap instead of, as in the 1932 type, being mounted horizontally on a turn table.

The mosquito-catching ability of the 1933 type is at least as great and perhaps greater than the 1932 type. No extensive changes have been made in this 1933 type, which has come into general use.

In 1932 traps were set along the Delaware Bay and Atlantic coasts and throughout the metropolitan district of northeastern New Jersey and have been continued each summer since that time.

Each day's catch is boxed, sent to the laboratory, identified and recorded. A sample of the daily record sheets appears as Fig. XI.

Since there are more than thirty traps in simultaneous operation each season and each trap runs for about ninety days, to save space only the total catches of each trap for the ten-year period beginning in 1932 and ending in 1941 are given in Table I.

4

MOSQUITO BIOLOGY *

GENERAL LIFE CYCLE

All mosquitoes go through a life cycle of four stages—adult, egg, larva (or wriggler), and pupa. The adult is a two-winged free-flying gnat varying from less than a quarter to fully one-half of an inch from head to tail. There are about an equal number of males and females. The females lay the eggs, small objects, just visible to the sharp naked eye, individually. From the egg hatches the larva, which is free-swimming and must have water charged with food materials and of favorable temperature in order to live. When larval development is complete the larva transforms to a pupa, which takes no food, but swims about through the water. This stage also requires water but can persist for some time in wet mud. During the pupal period changes go on within the pupal skin that transform the old larva into the winged adult. When the pupal period has been completed, the pupal skin over the thorax splits open longitudinally, the adult slowly draws itself out, the wings expand, the cuticle hardens, and the new adult flies away about its business.

In its relation to man, the species occurring in New Jersey may be classified into the following groups: salt marsh; household; fresh water swamp; woodland pool; malarial; and miscellaneous.

SALT MARSH BREEDING GROUP

[The notable members of the salt marsh group are *Aëdes cantator, A. sollicitans, A. taeniorhynchus, Anopheles crucians,* and *Culex salinarius.* The first three members of this group lay their eggs on the moist mud of the salt marshes to hatch when covered by water under suitable conditions while the last two lay their eggs on water surfaces to hatch as soon as temperature will permit. The first three are long distance fliers, the last two move over only limited distances. The first three winter in the egg stage, the last two winter in the adult form in sheltered places.]

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* The bulk of the material in this chapter has been taken directly from Dr. John B. Smith's 1904 *Report of the New Jersey Agricultural Experiment Station upon the Mosquitoes Occurring Within the State, Their Habits, Life History, etc.* The material used from Dr. Smith has not been put into direct quotation marks because parts have been deleted, and the wording in some instances changed. Interpolated paragraphs by the author are enclosed in brackets. All quotations from other sources are indicated.

Aëdes cantator Coquillet
The Brown Salt Marsh Mosquito

DISTRIBUTION AND CHARACTERIZATION

[North Atlantic Coast of the United States. Trapped 5,217 females in New Jersey.]

Large, robust, brown; thorax rather well covered with distinct spiny hair; beak not banded, wings not spotted, tarsi banded white or whitish at base of each joint, but bands not well marked and gradually merging into the ground color. Indefinite whitish bands on abdomen, not constricted in the center, diffuse toward apex, tend to cover entire segments.

DESCRIPTION OF THE ADULT

Measures 7 mm. long, exclusive of the beak, which is 3½ mm. long; 11 mm. across wings. Head yellowish brown, large black eyes take up sides and part of the top, beak dark brown, without markings, palpi in female short, dark brown, four-jointed, clothed partly with scales and set with moderately long hairs, the apical joint small, knob-like and retracted. Male palpi long, three-jointed, brownish black, paler at base, without markings, thickly scaled and with fan-like tufts of hair toward tip.

Male antennae plumose, half as long as palpi, brown, all joints cup-shaped with circle of long hair, except two terminal ones; these long, slender, covered with short hair, and base of apical joint with six long hairs. Antennae of female longer, very slender, approximately same number of joints as male, set with hair of irregular lengths and circle of six long, bristle-like hairs at base.

Thorax reddish brown, clothed with short, upright, golden-yellow hairs. Legs brown, femur paler, almost white beneath, with knees white. Tarsi blackish, all narrowly white-ringed at base; rings not well defined, merging into black and becoming almost obsolete toward tip on all feet.

In male, anterior claw-joint inwardly excavated, set with spines and bristles. Outer claw smaller than inner, both have single tooth in middle,

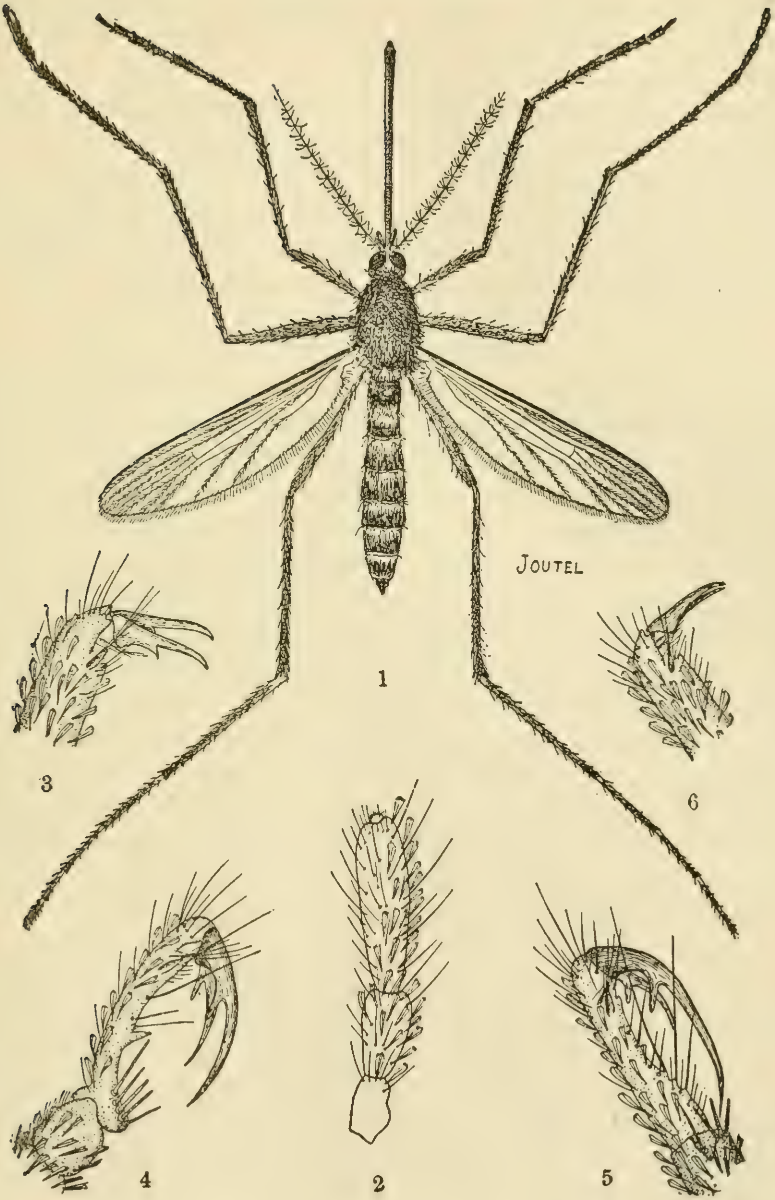


FIG. XII. Adult of brown salt marsh mosquito. *Aëdes cantator* Coq. (After John B. Smith.) 1, adult female; 2, palpus and 3, anterior claws of same; 4, anterior, 5, median and 6, posterior claws of male (all much enlarged).

slightly nearer base. Claw-joint of mid-tarsi only slightly excavated, claws same as of anterior tarsi. Posterior claw-joint normal, very small, with simple claws of same size.

Female anterior and mid claw-joints alike, single tooth on each of claws. Posterior joint of same size, claws simple, as in male.

Abdomen dark brownish black, yellowish white bands at base of each segment, considerably narrowed centrally. Bands become wide laterally, more noticeable posteriorly, and at segment seven broaden to entirely cover dorsal surface. Beneath, entire surface pale yellow.

HABITS OF THE ADULT

This species was not recognized as distinct until 1903, but was confused with both *stimulans* and *vexans*. It was this fact that prevented its recognition as a migrant in 1902, when I first met with the species in great numbers and found it as early as April, the dominant form in South Orange. In 1903 as early as March 23, larvae were well advanced at the edge of the Newark marsh, and adults began to issue during the early days of April. But it was not until the last days of the month that the bulk of the brood began to issue, and during the early days of May the migration was on in full force. May 12 they had reached South Orange, and by the middle of the month the entire countryside was covered with them. A second and much larger brood became started on the marshes late in May, and before the end of June was fully a-wing. Migration began during the last days of June and, north and west, locality after locality was covered to an extent greater than usual. *Sollicitans* was also in this swarm which filled the cities and towns bordering on the marsh as they had rarely been filled before.

On the morning of July 2, I was met when I stepped outdoors by a famished horde containing *sollicitans*, *taeniorhynchus*, and *cantator*. The preceding evening we had sat comfortably out on the porch, without disturbance from mosquitoes. The incoming horde settled the comfort for weeks thereafter. This same brood was traced to Plainfield, Dunellen, Bound Brook, and Somerville, where the migratory forms rarely get. The Newark swarm was traced to Summit and Morristown, and may have extended further.

In 1904 marsh conditions favored the early brood, and unusual swarms developed on the Raritan, Elizabeth, and Newark meadows early in May. By May 10 the whole marsh area was a-wing, except along the Shrewsbury, where the work done by the Monmouth Beach and Rumson Neck Associations completely annihilated the immense brood that was developing. The ditches were completed just in time to do their work. At New Brunswick the swarm arrived May 12, and extended onward. At Newark the invasion was almost unprecedented and compelled the closing of stores in some cases. This swarm not only reached Paterson, but covered the Garret Mountains, where they were swarming on June 11. It was reported further that it had extended to Bernardsville, well up in the hills, and far enough back to be beyond the reach of ordinary migrations. In the Pines, *cantator* reached Lahaway May 17, weeks ahead of the 1903 record.

There is one feature in which *cantator* differs from the other migratory forms, *i.e.*, both sexes fly together for some distance and occasionally females with developed ovaries are found far from any point where they can deposit them with any hope of development. The males are seen for a day or two only, but they arrive with the females and are evidently able to stand a flight of several miles at least. In Newark and Elizabeth both sexes may be taken on first arrival in equal numbers; at New Brunswick the males are numerous enough to "dance" in small swarms just at dusk. From Lahaway no males have been sent and my records are not sufficiently complete to give the limit of male flight.

While, as has been noted, occasional females with developed ovaries are found at some distance from shore, yet this is a feature only in the early arrivals; *i.e.*, they occur during the week or two after a flight and disappear, none being found during the later days of the brood's stay. Whether they make their way back to the marshes to oviposit, or whether they lay their eggs in the most likely place to be found, is not definitely known. As the percentage of such females is larger in Newark and Elizabeth than in New Brunswick, it is quite probable that many find their way back, and as an occasional brood of the larvae is found above the marsh line, it is possible that some may lay eggs which in most instances fail to develop.

In New Jersey *cantator* dominates the Newark, Elizabeth, and Raritan meadows early in the season. If the year is favorable, the early start will carry this dominance to midsummer or even through the summer. At the Barnegat shore *cantator* shares with *sollicitans* the early honors, but becomes steadily less as the season advances, leaving *sollicitans* in almost sole possession. At Atlantic City and Cape May I found no *cantator* during the period when they were swarming farther north, though the species does occur there in small numbers throughout the summer. Records show that they must have bred on the Mullica River marshes in greater number than *sollicitans* during the present year; but that is probably the southern limit of their dominance, and in ordinary seasons it does not extend so far. Just why they should be more plentiful on the northen marshes I do not know, nor what prevents their development along the southern shore.

Cantator enters houses freely where they are open; but is easily kept out by ordinary screening. It does not seek opportunities, but when attracted by light or the human odor it will come indoors much more readily than *sollicitans*. Among the indoor captures, this species is well represented throughout the season, scarcely yielding at times to *pipiens*. It comes to porches readily enough and does not hesitate about getting into the breeziest corners.

As a biter, *cantator* stands in the front rank, and it is persistent in its attack. It does no unnecessary singing, but proceeds to business at once, and while its bite is not so "hot" as that of *sollicitans*, it is really more painful and more lasting in its effects.

This species flies during the day and bites when opportunity offers; but it is not so active as *sollicitans* in this respect and rises only when disturbed. It is essentially an evening mosquito.

DESCRIPTION OF THE LARVA

When full grown 7–9 mm., (.28–.36 inch) long, excluding anal siphon; yellowish gray; young larvae almost white, darker when larger. Head broader than long, lighter than rest of body; maculation on vertex very constant, never diverging from type shown, each mark has well defined edges. Rarely diffused blotch near front, on top of head, which sometimes clouds whole head, partly obscuring maculation, giving darker or black appearance. Four tufts, each of three or four hairs, one pair a little in front of other, larger tuft at base of each antenna. Antenna short, single curve, dark brown, paler at base, sparsely set with short, stout spines. Tuft on shaft, little below middle composed of eight or ten hairs. At apex long and short spine, two bristles and small joint articulated to main segment. Eyes best seen from side, large, crescent-shaped, widest below, acute at vertex. Two sets of hairs compose rotary mouth brushes, very heavily pectinated set situated in center and simple set laterad. Mentum triangular, nine or ten teeth on each side of apex, sides well rounded, base flat. Rarely, sides in some specimens only slightly curved. Mandible normal, with few very small spines on dorsal surface of base. Maxillary palpus has large tuft of moderately long hairs. Thorax rounded, scarcely any angulations in full grown larva; in immature larva more transverse, distinctly angulated. Lateral hairs issue from number of tubercles at six points, two tufts small fine hairs at anterior margin. Abdominal segments one to seven oblong or subquadrate, each has tuft of lateral hairs, becoming

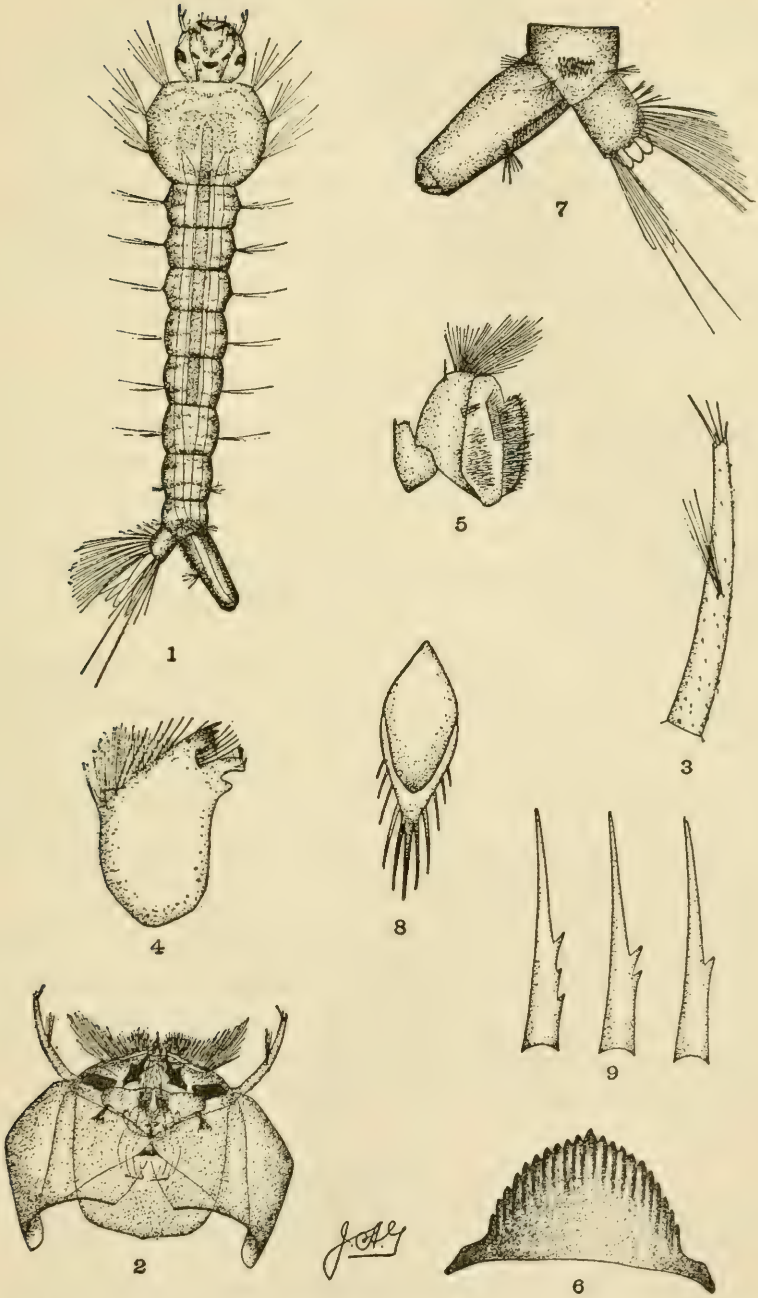


Fig. xiii. Larva of brown salt marsh mosquito. *Aëdes cantator* Coq. (After John B. Smith.) 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal segments and siphon; 8, single scale from eighth segment; 9, siphonal spines (all much enlarged).

shorter and fewer posteriorly. Eighth segment has lateral patches of scales, from thirty-five to forty in each patch. Scales fewer in young larvae, usually of same shape. Anal siphon two and one-half times as long as broad, with two rows barbed spines, sixteen to twenty-two in each row in full grown larva. Single spines have from one to three teeth. Ninth segment longer than wide, with barred area on ventral part, from which issue fourteen to sixteen tufts of four or five hairs each. Two tufts of hairs on dorsal apical margin, each with one very long hair. Anal gills vary from very short to long, but usually short. In young larva always short.

HABITS OF THE EARLY STAGES

Eggs laid as are *sollicitans*, but more abundantly and trifle larger. Under ordinary conditions, larvae found nearer upland; rarely on upland itself. Such cases probably from exceptional females developing eggs after leaving marsh.

Water, fresh, salt, or intermediate, but, fresh water pools formed by rains or drainage preferred. In exceptional season, like 1904, tide pools as well filled with larvae as others.

Eggs hatch readily as *sollicitans;* when young almost impossible to distinguish two species. As they become larger masculate head of *cantator* becomes obvious, and resembles *taeniorhynchus* so closely that without a lens impossible to discriminate between them. When full grown shorter tube of latter species and somewhat larger size of *cantator* give basis for distinction which requires experience to make. Pupa does not differ obviously from others with which found.

Number of broods depends on weather; in midsummer, when marshes become egg-covered, every heavy rain or extra tide means developing mass. Early brood hatching in March develops slowly and irregularly, adults appear early in April, all out by beginning of May. Not many larvae of second series before beginning of June; mature during last days of June. Thereafter larvae in some stage in every pool.

Aëdes sollicitans Walker

The White-Banded Salt Marsh Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Primarily on the Atlantic and Gulf Coasts of North America, Bahamas, Cuba, and Jamaica. Trapped 343,325 females in New Jersey.]

Broadly white-banded tarsi, white-banded beak, yellowish white bands at base abdominal segments, crossed longitudinally in center by broad continuous line of same color. Thorax golden brown; sides silvery white. This combination of characters in no other New Jersey species; recognizable at a glance.

DESCRIPTION OF THE ADULT

Medium sized or rather large; beautiful brown. Body, exclusive of beak, about 5.5–6 mm. (.22–.24 inch) long; beak averaging 2.5 mm. Head dark brown at base, scales of outer edges gradually mix with yellowish ones toward central part, bright creamy yellow between anterior part of eyes; narrow yellow border on posterior margin of eyes. Proboscis black, with well defined white central band. Palpi in female blackish brown, thickly scaled; apical joint elliptical, pointed at apex, usually with one or two bristles, though may not have any. In male, palpi shaped like *cantator*, but shorter, stouter, extending beyond tip of proboscis; two apical joints narrowly white-banded at bases, broader yellowish band in center of basal joint; fan-like tufts pale yellowish brown. Female antennae dark brown, male brown with pale brown plumes.

Clothing on dorsum of thorax spiny, deep brown; numerous golden yellow scales often form two diffuse longitudinal rows; lateral margins blackish brown, deeply contrast with silvery white pleura. Femora and tibiae ochraceous, many black scales sprinkled over surface; knee spots yellowish without scales, apices of tibiae black. Tarsi in hind legs black, broadly white-banded at bases of three intermediate joints; fifth joint wholly white, first narrowly white-banded at base, with distinct ochraceous median band. Fore and mid tarsi similar to hind, except bands dirty white, proportionately narrower, disappearing altogether on fourth joint; ochraceous band on first tarsal joint less distinct; fifth joint with some dark colored scales. In male claws of anterior and mid tarsal joints unequal, the longer with median and basal tooth, the shorter with median tooth slightly nearer base. Posterior claws small and equal, with single tooth on each. Those of female alike on all feet, being same as posterior claws of male.

Abdomen dark brown, with broad yellowish bands at base of segments, becoming slightly wider laterally; longitudinal stripe entire length of abdomen across bands in center, dividing body color into blocks. On two apical segments white spots laterally near base. Bands and stripe generally well defined, but specimens common where very much diffused, apical segments being entirely yellow and blocks appearing as irregular spots. Dirty yellow or grayish beneath.

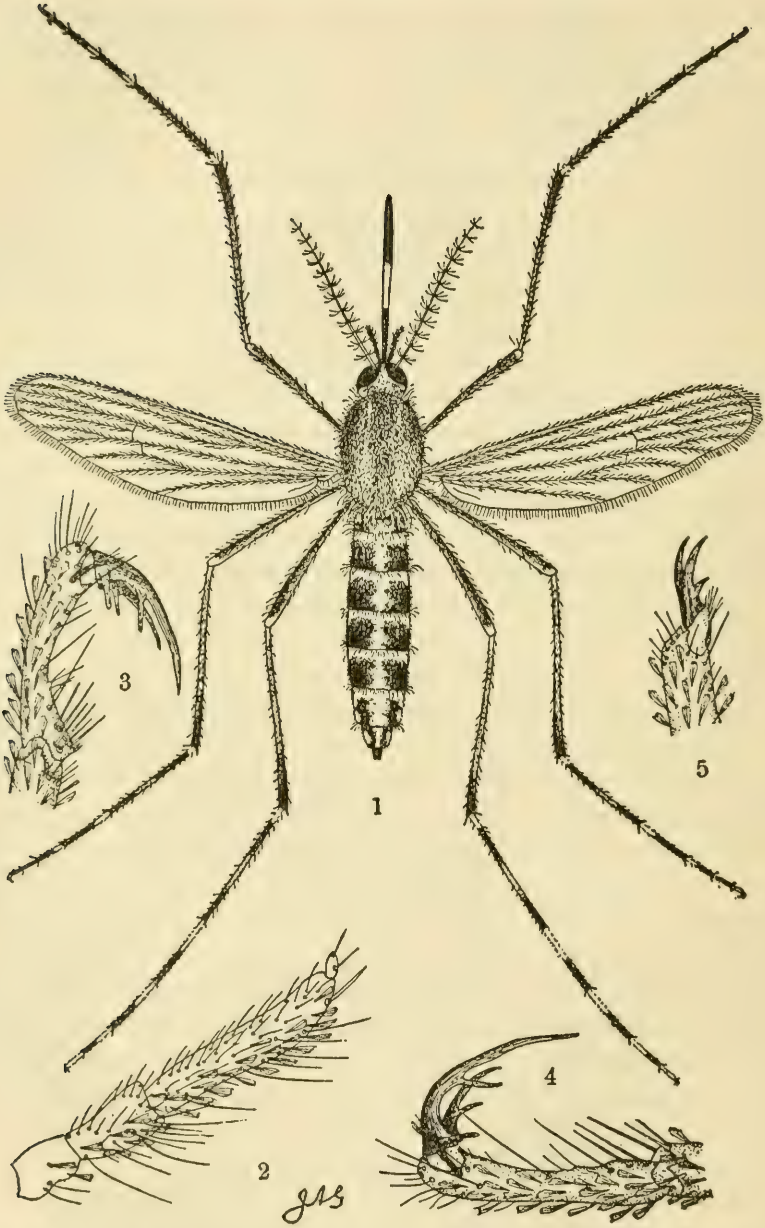


FIG. XIV. Adult white-banded salt marsh mosquito. *Aëdes sollicitans* Walk. (After John B. Smith.) 1, adult female; 2, palpus; 3, anterior, 4, median and 5, posterior claws of male (much enlarged).

HABITS OF THE ADULT

Sollicitans, the most common mosquito in New Jersey, breeds only on the salt marshes in such numbers that he is a bold man who would agree to stand quietly on some marshes for any considerable period of time. Records are not wanting of persons driven almost frantic by them, and sensational stories are sometimes set afloat that individuals have been unconscious or delirious from their bites. *Sollicitans* bite hard, rapidly, without much preliminary singing, and as readily during the day as the evening. Ordinarily they hide in grass or low bushes during the day, do not voluntarily rise if undisturbed, but if disturbed rise in a cloud in a moment. No one who has not met with *sollicitans* on their native heath can have any idea of what a swarm really means. I am tolerably well seasoned myself and have been with collectors and fishermen who claimed to be practically mosquito proof, but we were on one occasion simply driven out of a woodland at the edge of a marsh along Seven-Mile Beach. But not only in their breeding area are they so troublesome: miles inland I have battled with them on cranberry bogs while studying the pests of that crop, and have been glad to get away, wringing wet with perspiration, smarting with bites on every exposed part of the body and on some parts that became so closely covered when stooping that the insects struck blood through the clothing.

When the wind blows hard enough to make flight difficult during the day, the insects crawl up the legs of the victims, probing until they find a place to attack, causing untold suffering, especially on exposed legs of children.

It is no exaggeration to say that half the pleasure derivable in the resorts along the New Jersey Coast is lost because of the annoyance caused by this species. It has one good point, however; it does not make any special effort to get indoors. At New Brunswick, where my house is fairly well screened, *sollicitans* does not get in more than once or twice during the summer, while *Culex pipiens* and *Anopheles punctipennis* work their way in despite screens. Even along shore the indoor mosquitoes are nearly always *pipiens*, though *sollicitans* may be plentiful outside.

A large proportion of all the female specimens of this species that mature on the marsh leave it soon after they are fully developed and fly inland—a longer or shorter distance, as conditions may determine. All these migrants are sterile, and no matter how small the brood on the marsh, some of them always fly from it. From these breeding places the species covers the entire Cape May peninsula—practically the entire pine area—extends up the Delaware nearly to Philadelphia; indeed, it does reach the Philadelphia Neck in some seasons, and in general reaches inland a distance from twenty to forty miles. Assisted by *cantator*, it dominates the territory to the top of the first ridge of the Orange or Watchung Mountains, and sometimes extends beyond to the second ridge. From the Newark meadows it extends north to Paterson and covers all the intermediate territory. It does not in this territory quite equal *cantator* in number and distribution. On the marshes the species appears late in April, or early in May, and usually lasts until late October.

I have seen both sexes of this species feeding on the blossoms of wild cherry, and it is quite probable that vegetable juices form a considerable element in the food of this species. Howard, Dyar, and Knab record the observation of Dr. C. R. Ely to the effect that Ely had taken females at sugar bait when collecting moths. As to the number of broods, that depends altogether upon weather and tide conditions, from five to eight being, perhaps, usual.

EGG-LAYING HABITS

During the early summer of 1902 Mr. Dickerson and myself planted a series of eight tubs on the land of the Keystone Rod and Gun Club, which were meant to represent various marsh conditions, and stocked these with larvae, pupae, and adults of *sollicitans*, covering with netting to control the outcome, but leaving two open to the swarms infesting the surrounding meadow. We found gravid females abundant in certain places and confined a number of them in quart jars under varying conditions. Some jars had water and some had none; some had vegetation, others only bare marsh mud, and so altogether about a dozen jars were prepared, each to receive from two to ten gravid females. Next morning a large proportion of the jars had eggs, all of them black and laid under so many conditions that conclusions were difficult. Another series of captures, when carefully examined, led us to believe that the eggs became black within the ovary of the female, and that they were of that color when laid.

The tub experiments, details of which need not be given, indicated that the marsh mud was the place to look for the eggs of *sollicitans*, and some pieces of sod from an old breeding area were at once secured. The result was that in twelve hours we had a large brood of baby wrigglers and had demonstrated, by actual observation, that the marsh mud everywhere round about was more or less densely covered with mosquito eggs; most densely in the lowest, damp areas. Other observations made during the year confirmed this conclusion, and a series of laboratory experiments with sods brought to New Brunswick showed that the eggs might survive an almost complete drying out; not for a day or a week, but for months; hatching promptly as soon as they became water covered.

Mr. Viereck's experiments conducted at the Cape May Station in 1903, give the following conclusions:

July 24, placed one dozen gravid females into each one of two quart jars, in which bottom was thinly covered with marsh sod. July 25, some were dead, only three females had abdomen yet distended. July 27, only three living specimens remained, in these the abdomen was collapsed. July 28, all were dead. July 30, the sod was examined and black eggs were found, most of which must have been laid during the night of July 24. The eggs were evidently white when laid and became black subsequently. It rained during the night of July 29, and water covered the bottom of one of the jars in which baby wrigglers were found on the thirtieth. These lived until August 5, when only a few survived. On the sixth, a new lot of babies hatched and some sound eggs yet remained in the sod. Only a few eggs in this series collapsed.

August 2, prepared two one-quart jars with moist lint at the bottom and two others with lint covered with moist marsh mud, which had been sterilized to make certain no live eggs were introduced. Ten gravid females were placed in each and oviposition began while the jars were yet under observation. One specimen extended its ovipositor, darted its end into the sod until it found a suitable place, then laid six eggs, one after the other, and flew off. Another placed fifty-two eggs, one by one, in an irregular row about an inch long, in one continuous laying. A third took great pains hunting up a suitable place by darting its ovipositor in many directions before placing each egg. At 6:00 P.M., and a few minutes after, an injured female laid all its eggs in a heap, one by one, but rapidly. At 7:30 P.M., those first laid were black, the rest assuming a gray color and becoming black from the end first laid to the end last to appear. Some of the eggs were placed and kept in a dark place, but these blackened as rapidly as did those kept in the light. Eggs taken from the ovary of a female ready to lay, perfect in size and form, failed to darken in color, and collapsed.

August 3, eggs of this second series were placed in four jars and covered with sea water 100 per cent, sea water fifty per cent, sea water twenty-five per cent, and pure artesian spring water. No larvae had hatched in any of these jars August 6, after being covered for seventy-two hours, and the water was then poured off, leaving only a little moisture. August 10, again covered the eggs in the fresh water jar with water of the same kind and wrigglers hatched at once. The same experience resulted with the other jars, tending to show that the eggs must be at least partially exposed before they hatch. Eggs of this series that had been kept nearly dry since they were laid, were covered with water at 3:35 P.M., August 8, at 4:08 P.M. wrigglers had begun to emerge. August 13, tested jar four in which the sod was completely dry and found the eggs hatching after one and one-half hours. August 15, poured water over the entire sod and wrigglers began to appear in three minutes! Adults from this lot were obtained August 24. September 23, some eggs of this series that had been kept in a damp closet since laid, were covered with water and hatched within an hour afterward.

August 4, the third series of experiments was started and a dozen jars were stocked, each with ten gravid females. In the jars which contained only dry lint no eggs had been laid up to August 6, when the jars were brought indoors. August 8, the eggs in the jars in which the lint had been allowed to get perfectly dry after the insects had oviposited were found collapsed. At noon, August 8, put water into jars seven and eight, and at 3:00 P.M. wrigglers were present. These jars were put out in the marsh August 12, and some ditch water was added. August 15, put the young larvae into a small artificial pond and re-covered the sod with marsh water. On the nineteenth, there was another lot of young larvae in the jars, while those in the small pond were approaching pupation. August 11, added water to another jar of this series and on the twelfth, larvae were found. On the twenty-fifth, there was a fresh hatching from this series, and this left some eggs still in good condition.

The fourth series was started August 14, twelve or more gravid specimens being confined in each of twelve jars containing as follows: number one, dry sand; number two, wet sand; number three, dry lint; number four, wet lint; numbers five to twelve inclusive, ordinary upland soil over moist lint. Not all the specimens had laid eggs on the fifteenth, and some were yet alive on the nineteenth. In jar four the lint was so saturated that the water just failed of flowing it and here the insects were tempted to lay eggs on the sides of the jar an inch above the wet bottom. August 19, the eggs in jar number eight, were covered with water, but no larvae hatched from this series. Some of the eggs in jar four became covered with water September 1 and hatched. September 5, another lot was covered and also hatched. Some of the eggs were covered with water soon after they were laid and were kept covered until September 5 when, no larvae having hatched, the water was poured off and they were allowed to dry. September 23, when these eggs were again covered with water they hatched freely. Eggs that had been kept dry since laid were covered with water September 5, and hatched. Eggs kept under similar conditions, one series on marsh mud, the other on upland soil, were covered with water September 30. Five hours later wrigglers were found over the marsh mud; but three days later none had yet appeared over the upland soil!

In one case a number of gravid females were caught in a net with a mass of other material. This was all placed in a jar and the mosquitoes began ovipositing at once, in masses. Only a few of the eggs had turned black twenty-four hours later when they were covered with water. A small number of these black eggs hatched; all of the white examples collapsed.

Some other experiments were made and from those as well as from the above record, Mr. Viereck concludes as follows: No black eggs were laid and only one specimen was found with black eggs in it. All eggs laid outdoors (presumably) and in the experiment jars (certainly) were white when laid. They changed from white to steel color and then to black, gradually, in one hour and a half. Eggs were laid on moist material, but not in water, nor on dry sand or lint. Some hatched overnight when the fresh eggs were covered after having turned black; but usually they did not hatch until two or three days had intervened before they were covered with water. One lot placed under water did not hatch in weeks; these eggs when dried and again covered with water, did hatch. In one jar several hatchings took place at intervals of three days. Eggs kept indoors and exposed to the air of the room collapsed. Eggs under the influence of the moisture of a closet did not collapse when in the mold of black grass marsh, but did collapse when the material was ordinary garden soil or lint. Eggs hatched in all percentages of sea water, their further progress depending on food. Larvae died in water at 40°C. (103°F.); they survived at 37°C. (98°F.). Mr. Viereck is further of the opinion that whether the eggs will collapse or not after being laid, depends also on the stage of development when they are laid: thus, those fully developed remain entire, while those not so mature, such as the ones laid by an injured female, need moisture to develop them further.

The general statement here made is undoubtedly correct, but it should be added that the records indicate that the eggs laid under such stress as Mr. Viereck indicates are not fertilized, and, therefore, not viable in any event. It should be further noted that the apparent difference between Mr. Viereck and myself concerning the color of the eggs when laid is open to a very simple explanation. When my observations were made there had been a drought of considerable length, and inviting places for oviposition were few and far between. This had delayed the females in their work of providing for a continuation of their kind; yet development of the ova had gone on within the body and a considerable percentage changed color. This coupled with the fact that only black eggs were found in the marsh mud, justified my belief that the eggs became black before being deposited. Mr. Viereck's conclusions undoubtedly state the rule.

CONCLUSIONS FROM THE OBSERVATIONS

Egg-laying may begin as early as a week after development into the adult condition. This is based upon observations made late in July on specimens of the brood then recently hatched. There are no direct observations as to how long a specimen may live before eggs are laid. We have assumed that all the eggs which a specimen of this species is capable of developing mature at one time, and the limit in number observed for one female is close to 200. We have no positive experiments to prove that this is so; but examinations made of females that have oviposited showed a rigid thickened abdominal wall and an entire absence of ovarian structures. There was simply a hollow shell in which only the digestive system remained, and the worn looking specimens died readily in confinement. Yet I am assured by Dr. Dupree, of Baton Rouge, Louisiana, that *sollicitans* lays several batches of eggs in that state, and has a much wider range of breeding places than in New Jersey.

No eggs were laid in water or on its surface. This is an important fact because it eliminates permanent bodies of water as breeders of this particular species. *The eggs must be dry or at least not water covered for at least twenty-four hours after they are laid;* otherwise they will not hatch. On the other hand, these eggs may remain dry for three months or longer, without losing vitality, and if at any time after they have been dry for over a week or two they become covered with water, hatching is rather a matter of minutes than of hours. I have seen a low meadow covered with an inch of water from a heavy storm, and have found this water swarming with wrigglers a few hours afterward. After two days of sunshine the water had disappeared and with it the millions of larvae. Slow drainage is a positive advantage in danger areas for it will induce the eggs to hatch on a high tide or heavy storm and will destroy the resulting brood. This is an advantage because it absolutely eliminates just that many possible adults and will come nearer to actual extermination in the long run than any other possible method. Mr. Viereck's experiments also prove, what I suspected as the result of my own observations; that a certain percentage of the eggs laid did not hatch when first covered with water. This is a provision of nature for the continuance of the species; that in case of a covering too slight to bring the brood to maturity, there should be a remnant lying over until a later period, ready to hatch at the second or third covering, or until the spring following. In other words, the evidence tends to show that out of say 200 eggs laid by an individual, 100 would hatch the first time they were covered with water provided the eggs had been uncovered for at least twenty-four hours. Of the remainder, fifty would probably hatch at the second covering and of the balance, ten would lie over until the season following, while the others would hatch if covered during the season. Assuming however that of the 200 eggs from an individual of the first brood, none was covered by water during the summer for a long enough time to produce the larva, the indications are that at least fifty per cent would lie over safely until the season following, ready to take advantage of spring conditions.

As for the points selected for oviposition by the females, that includes practically every damp place on the salt marsh and the country immediately adjacent thereto. For example, a cornfield noted by Mr. Viereck came down to a corner edging on the marsh, and while it was plowed and planted like the rest, a pool which formed in that marsh corner contained *sollicitans* larvae while none were found in apparently much more attractive places away from the direct salt marsh influence. Where a shore town has been laid out with streets and avenues running in all directions through a salt area, the depressions between the streets retain their salt character and will breed *sollicitans* whenever water gathers, though they may be dry from June 1 to December 1. I have in mind several places of this kind which become water covered in winter only, remain water covered until late in May or early in June and mature a brood composed of practically all the eggs that were laid on that place during the preceding season. There is no water from June 1 or thereabouts until frost; but mosquitoes are always there and eggs are laid freely.

On the other hand, once out of the immediate influence of the marsh, neither eggs nor larvae are found, no matter how abundant the adults may be. This is a point which I have tested and had tested again and again, every one of my assistants having collected within the range of *sollicitans* from the salt marsh to the inland, and all having had exactly the same results, whether they collected blindly on definite instructions, or intelligently, with a direct knowledge of the point they were detailed to clear up.

Mr. Viereck's collections and notes are especially valuable on this point, for the Cape May Peninsula is comparatively narrow, is thoroughly dominated by *sollicitans* and was explored in almost every section. The net result of Mr. Viereck's collections is exactly that of all others who have done similar work. There is no breeding away from the salt marsh region broadly considered.

It is not necessary that there should be any considerable depth to the mud in which the eggs are laid. I have never found larvae in pools with a clear sandy bottom; but I have found them in grassy depressions among the sand hills, where there was just a scum of the organic mud deposit on the surface.

DESCRIPTION OF THE LARVA

When full grown, from 8–9 mm. (.32–.36 inch) long. Large, robust, usually dirty gray, often yellowish white. Head yellow, small in comparison to body, one and one-half times as broad as long. Sides and base shaded reddish brown; vertex, though immaculate, generally has lateral blotches, often clouded in front. Rarely, dark clouded head, due to extension of anterior blotch. Four rather long, single hairs arise from sides of vertex in anterior part, two slightly in advance of others, small tuft of four or five hairs at base of each antenna. Antennae short, evenly tapered toward apex; pale yellow at base, dark brown on apical half, with small stout spines over surface. Tuft of four or five hairs issues from shaft about middle, few short bristles besides small joint on apex. Eyes large, some blunt, others acute on dorsal surface. Rotary mouth brushes have more central hairs pectinated. Mentum triangular; eight to twelve teeth on each side of apex. Mandible normal, somewhat elongated; maxillary palpus short, chunky, hairy surfaced, large basal joint, comparatively very small apical tuft.

Thorax large, wider than long, two transverse depressions on dorsal surface, number of smaller wrinkles. Angulations not very prominent, hair tufts arising from them very short; two other small tufts on dorsum near anterior margin.

Abdominal segments subquadrate; joints more constricted in anterior segments. Hair tufts very short, two hairs to lateral tuft, more in first, second, and seventh segments. Eighth segment has from twenty to forty lateral patches of scales, single scale drawn to acute point at apex, with small spines fringing sides. Anal siphon short and stubby, about one and one-half or twice as long as broad, with two rows of

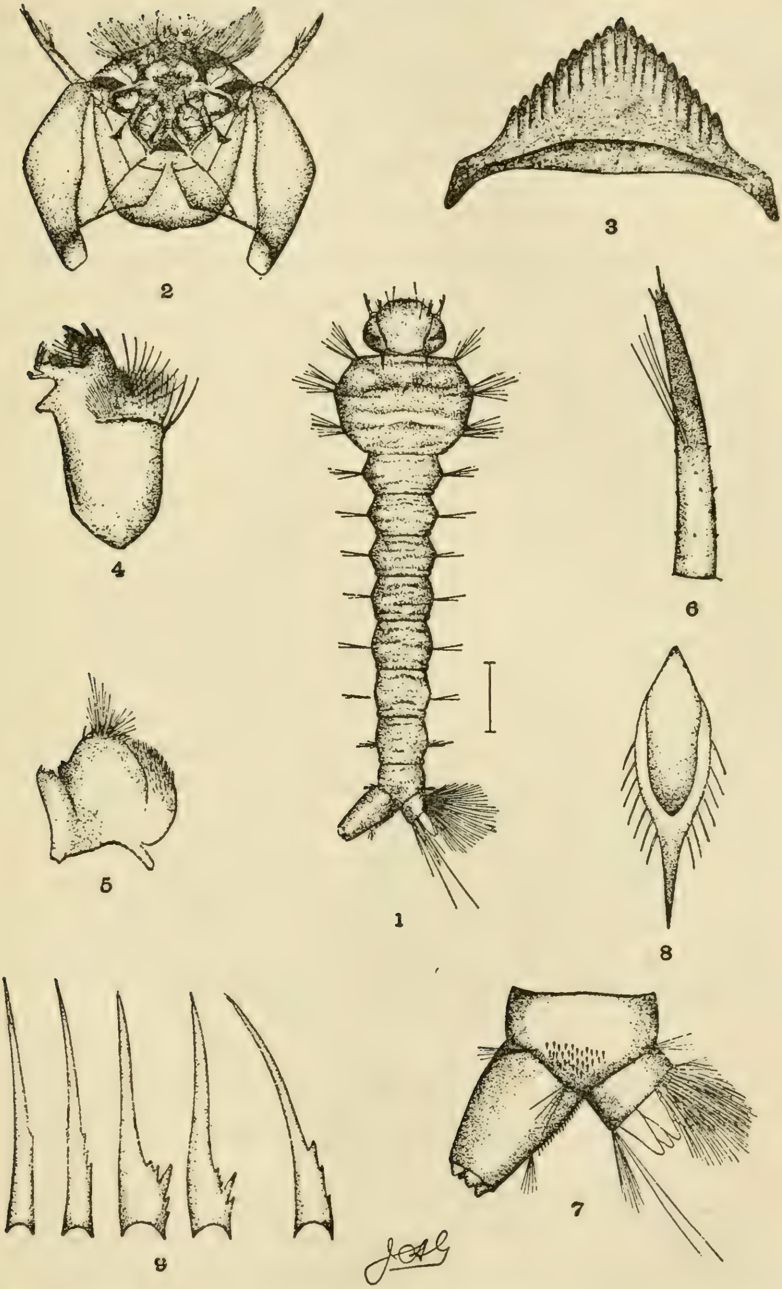


FIG. XV. Larva of white-banded salt marsh mosquito. *Aëdes sollicitans* Walk. (After John B. Smith.) 1, larva; 2, head; 3, mentum; 4, mandible; 5, maxilla; 6, antenna; 7, terminal segments and siphon; 8, a single scale; 9, siphonal spines showing variation (all much enlarged).

toothed spines from sixteen to twenty-four in each. Spines have from one to five teeth, may be either slender or stout. Ninth segment small, almost square, completely ringed by chitinized saddle. Dorsal tufts normal; ventral brush thick, short hairs; tufts confined to barred area. Anal gills very short, often no longer than wide.

HABITS OF THE EARLY STAGES

When the eggs become covered with water by rains or by the tides the larvae develop and emerge, often within a period of minutes rather than hours. A week is all that is necessary to bring the larva to maturity, and the pupal stage is short or long, according to temperature.

At Anglesea young larvae were taken as early as March 5, though development at that period is slow. On March 12 larvae were more abundant and evidently developing generally. At that time the temperature of the water in which larvae occurred ranged from 42°F. to 50°F. At this temperature microscopic life multiplies slowly and the wriggler food supply is limited; therefore this first brood of larvae dawdles along for a month before adults are ready to emerge. Breeding continues until early October; but after that few eggs remain to be developed, except for the spring following. If the wriggler succeeds in reaching the pupal stage before a pool dries up it is usually safe, for the pupa will live twenty-four hours in soft mud and develop as an adult; indeed not more than twelve hours is really needed. Larvae more than half grown will survive in soft mud a few hours, and if the pool is then refilled by rain or tide will revive and complete their transformations.

In its actions or method of feeding the larva offers nothing out of the usual course, and it is readily subject to the effect of oils and other coverings. As a rule the water it inhabits is tolerably clean, but it is able to sustain itself in quite foul and fermenting pools.

Aëdes taeniorhynchus Wiedman
The Small Salt Marsh Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Atlantic Coast of America, exclusive of Antilles and on Pacific Coast from southern California southward. Commonest coastal species in warmer parts of continental America. Replaced by closely related forms in Antilles, on west coast of South America, on some Pacific Islands. Trapped 7,701 females in New Jersey.]

Small, black with narrow white bands at base of abdomen. Narrow white ring at center of beak, legs ringed with moderate white bands at bases of tarsal joints; last joint of hind feet entirely white. Worn specimen might be taken for undersized *A. sollicitans*, but has no longitudinal stripe on abdomen.

DESCRIPTION OF THE ADULT

Small, between 4–5 mm. (.16–.20 inch), exclusive of beak, which is about 2.4 mm. long. Head dark brown, few yellowish scales, which sometimes make diffused patch in angle formed by eyes; proboscis blackish brown with creamy white ring at about center, slightly nearer base. Palpi in female brown, become blacker distally, extreme tips pure white; terminal joint small, almost rounded, covered with short, fine spines. In male, palpi shaped something like those of *sollicitans*, but not so robust, terminal joint shorter; black, with narrow white rings at base of two terminal joints; wider yellowish ring in center of basal joint. Fan-like tufts brown with yellow sheen. Antennae brown in both sexes, plumes in the male pale brown.

Thorax brown, darker laterally, some yellowish scales over surface; pleura, brown with patches of dirty white scales. Femora black above,

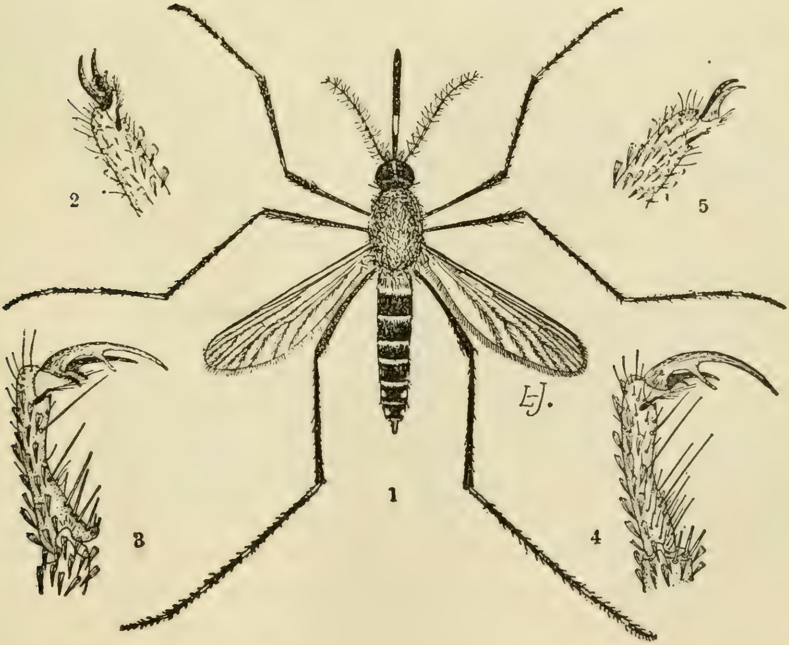


Fig. xvi. Adult of small salt marsh mosquito. *Aëdes taeniorhynchus* Wied. (After John B. Smith.) 1, adult female; 2, anterior claws; 3, anterior, 4, median and 5, posterior claws of male (all much enlarged).

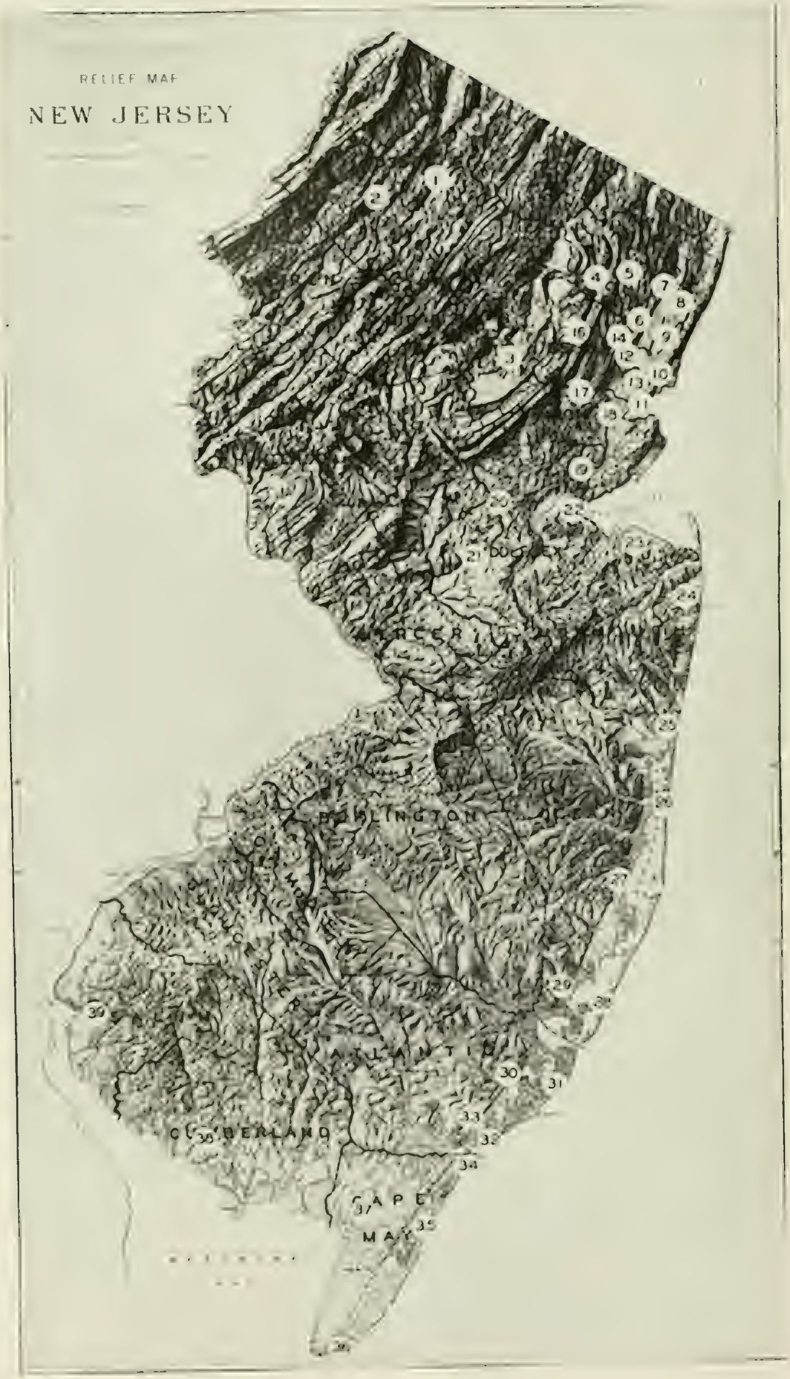
pale yellowish beneath, very few yellow scales; black meets on underside near apex; knee spot small yellowish dot. Tibiae black, spotted with yellow scales, either black or yellowish beneath. Tarsi black, anterior and middle narrowly white-ringed at bases of first three joints, obsolete or entirely absent in fourth; fifth, paler, without band. Posterior tarsi have pure white bands, about double width of anterior and middle, on all but apical joint. Apical joint entirely white or white with black tip. Claws of anterior and mid tarsal joints in male unequal in length, long claw of anterior has median and basal teeth, shorter claw only single tooth near base. In mid tarsus each claw has single tooth. Posterior claws equal, simple, rather sharply curved toward apices. Claws of female equal on all feet, one-toothed in anterior and mid tarsal joints, simple in hind pair as in male.

Abdomen black, each segment with narrow basal band of white crossing segments, with small lateral white spots beginning on second segment, becoming larger posteriorly. In apical two or three segments they encroach well upon dorsal surface. Beneath, yellowish brown, apically banded with black.

HABITS OF THE ADULT

In a general way, the habits of this species are like those of *sollicitans*, but it is not nearly so abundant. It is strictly a marsh mosquito, and has never been bred anywhere else, but it also migrates, though not so generally and not so far. It reaches New Brunswick from the Raritan meadows in small numbers, but it has never been sent in from Lahaway, so that it is distinctly inferior in its spread to both *sollicitans* and *cantator*. Nor is it equally abundant throughout its range. From the sections north of Barnegat Bay, collections early in the season have shown few or no specimens: later they become more abundant; but from two to ten per cent of the bred specimens was the best secured at any time. At Atlantic City I found the species active and biting during the day quite as abundantly as *sollicitans*. At Anglesea a series of porch captures in August made during the later afternoon, showed both species equally present. I have never observed *taeniorhynchus* crawl up the legs of the marsh tramper as its ally does, but it may do so where it is most abundant. Late in the season a lot of specimens attracted to the electric lights were collected and found mostly gravid examples of *taeniorhynchus*, *sollicitans*, *salinarius*, and *crucians*. *Sollicitans* is also difficult to take when ready to oviposit, but it may be obtained by close sweeping of the grass in the early evening. *Taeniorhynchus* apparently refuses all invitations and hugs the ground until dark. Just why the

PLATE I. TOP. Cooperator taking the catch from a New Jersey mosquito trap. BOTTOM. Identifying the catch in the laboratory.


RELIEF MAP
NEW JERSEY
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MERCER
BURLINGTON
ATLANTIC
CUMBERLAND
CAPE
MAY

Plate ii. Relief map of New Jersey showing mosquito gauge locations.

light has a special attraction for gravid females it seems difficult to determine.

As to the bite, that is much like that of *sollicitans* and, like that species, *taeniorhynchus* takes no long thought in reaching a proper spot; any exposed place will answer and it has the same ankle-seeking propensity that its allies have. I have never taken it indoors, even along shore.

The egg laying habits are like those of *sollicitans* and the eggs themselves have not been found separable from those of its ally. In fact in my first experiments I bred more *taeniorhynchus* than I did *sollicitans* from the egg-filled sods collected.

DESCRIPTION OF THE LARVA

Scarcely distinguishable from *A. sollicitans* in outline and color, and breeds in same pools. Seven to eight mm. (.28–32 inch) long to end of ninth segment, dirty gray or yellowish, head one and one-half times as broad as long and usually pale yellow; sides and front shaded with brown; sometimes sides of vertex bisymmetrically marked. Faint crescent-shaped mark, with black spot in advance and four others to rear usually present, though one or more, or occasionally all, are commonly absent. On front of head four single hairs from individual pits, each pair separated laterally. Small tuft of four or five hairs at base of each antenna. Antenna short and slender, with only slight reverse curve, apical half dark, light yellowish toward base; surface with small scattered spines. Tuft situated on shaft at about middle, has two or three moderate sized hairs; apex has few short bristles and one longer one, besides small joint. Rotary mouth brushes have central hairs pectinated at tip. Mandible and maxillary palpus similar to *sollicitans*, palpus shaped a little differently, with long apical tuft. Mentum triangular, ten or twelve teeth on each side of apex, very little variation in form, differences chiefly in curve at sides.

Thorax wider than long, transversely depressed on dorsal surface, lateral hair tufts short, two very small tufts near anterior margin.

Abdominal segments normal, four or five short hairs to lateral tuft in anterior two segments, fewer in posterior. Eighth segment has small lateral patches of from sixteen to twenty-two oval scales.

Anal siphon grayish about one and one-half times as long as broad. Two rows of spines, from twelve to sixteen in each row, extend beyond middle with a small terminating tuft. Spines of moderate length, becoming short toward base and peculiar by being toothed on both sides. The ninth segment square or broader than long, with hairs of double

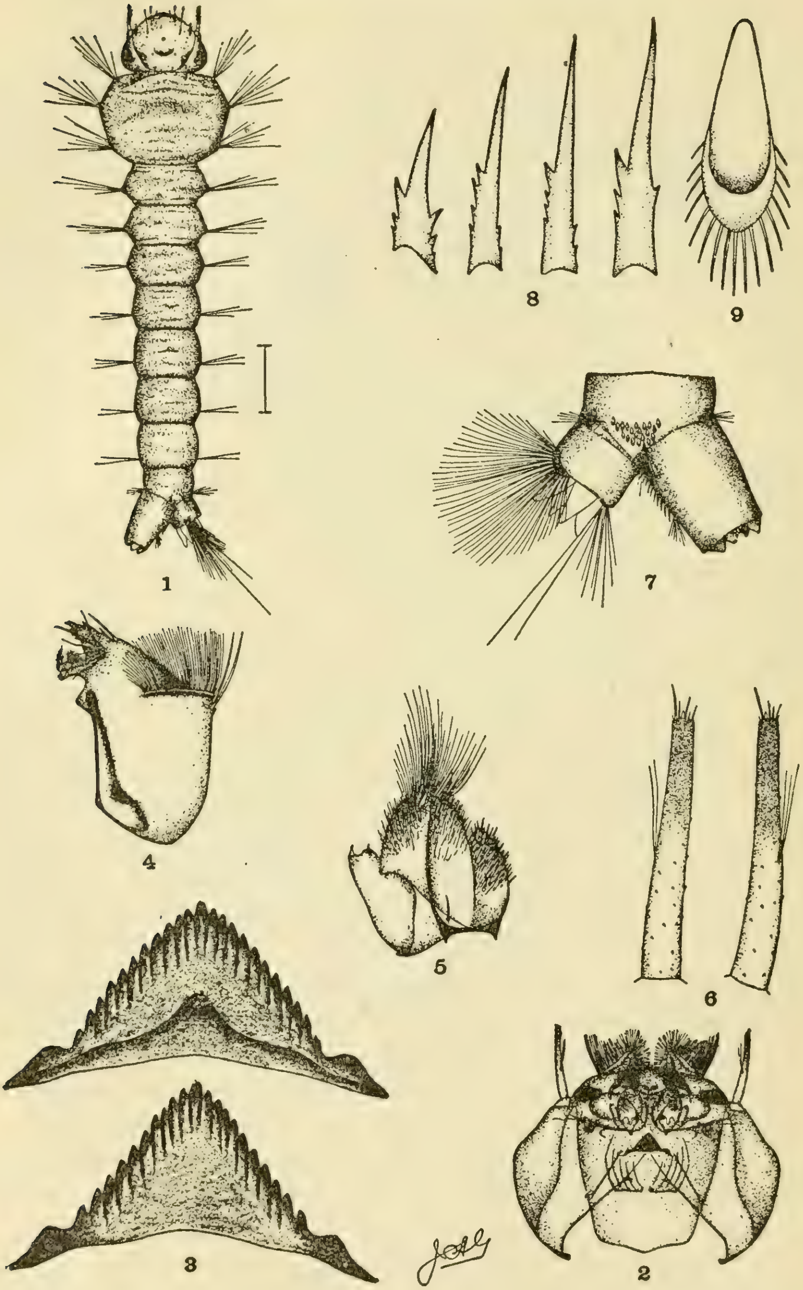


Fig. xvii. Larva of small salt marsh mosquito *Aëdes taeniorhynchus* Wied. (After John B. Smith.) 1, larva; 2, head from below; 3, mentum; 4, mandible; 5, maxilla; 6, antennae; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale of eighth segment (enlarged).

dorsal tuft and ventral brush shorter than normal, completely encircled by chitinized saddle; gills very short; often no longer than broad.

HABITS OF THE EARLY STAGES

The larvae of *taeniorhynchus* occur with those of *sollicitans* and *cantator*, and the habits are similar to those species. None of our collections show larvae of this species only; as a rule they are in the small minority. In a mass of partly grown larvae there is little apparent difference between the three species, but when full grown the maculate heads of *cantator* and *taeniorhynchus* are characteristic, while the very short anal siphon distinguishes *taeniorhynchus* from *cantator*. As the species is more southern in its range, *sollicitans* is its companion more frequently than *cantator*.

Anopheles crucians Wiedman

The Daylight Anopheles

DISTRIBUTION AND CHARACTERIZATION

[Seacoast of southeastern United States from New York to Texas. Trapped 26,717 females in New Jersey.]

Smallest of New Jersey *Anopheles* species, some specimens as large as *An. punctipennis*. Brown, not quite as dark as *punctipennis*, thorax striped with grayish scales, wing veins clothed with whitish and black scales, black ones especially collected along the wing margin.

DESCRIPTION OF THE ADULT

Species averages 4–5 mm. (.16–.20 inch) long, beak about half as long as body. Head dark brown with scattered yellowish scales at angle of eyes; tuft of yellowish hair from between eyes projects forward over head. Narrow line of similarly colored scales forms border to posterior margin of eyes. Proboscis evenly dark brown. Palpi in female same in shape as other species of *Anopheles*, but dark brown, almost black, with apical joint, base of penultimate and of antepenultimate joints white. Male palpi dark brown with long yellowish hairs toward apex. Antennae dark brown in female, paler in male.

Dorsum of thorax brown, mottled at sides with grayish scales, narrow stripes of grayish scales down central part; pleura and legs same as in *punctipennis*, but latter not nearly as dark. Wings hyaline, with black, whitish, and gray scales as follows: costa, black; subcosta, black;

radius one, black; few white scales at extreme apex and some grayish ones just before cross vein between radius one and radius two; radius two, black, broken twice with white portions before fork and white again at margin; radius three, large portion at base black, smaller portion black at margin, intermediate part white; radius four and five, black at base and at margin, grayish and whitish scales between; media one and two, grayish to fork, with small black patch at cross vein, after fork black at both ends, white between; media three, black at both ends, white between; cubitus one, white to fork, black to a little beyond cross vein and again at wing margin, intermediate part white; cubitus two, white, except small black portion at margin; anal vein, white, small black portion at each end and one in center. *An. crucians* is the only species in which the last spotted wing vein has three distinct spots.

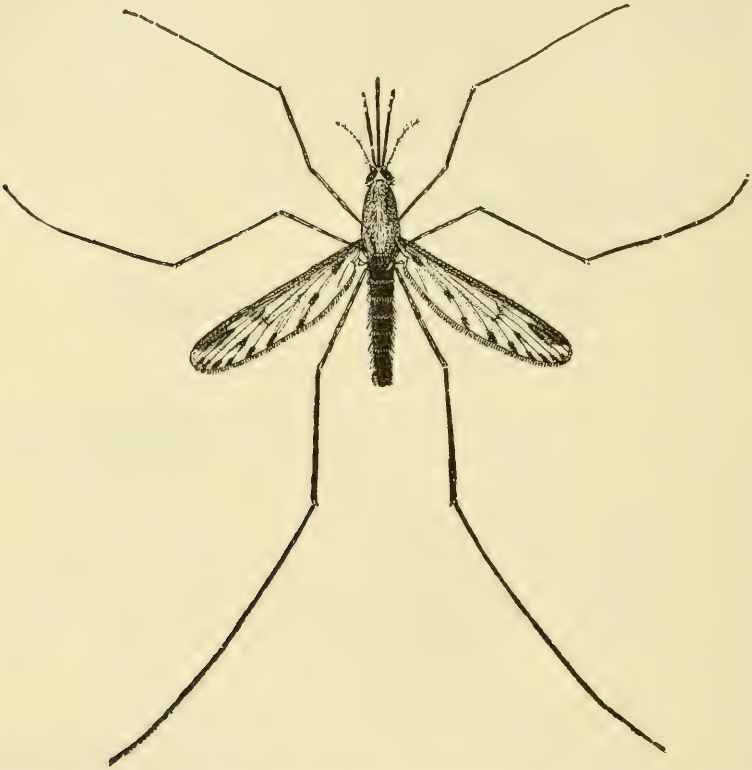


Fig. xviii. Adult of daylight Anopheles. *Anopheles crucians* Wied. (After John B. Smith.)

Abdomen, as in allied species, dark brown with yellowish brown hairs evenly scattered over surface.

HABITS OF THE ADULT

This species flies and bites freely long before dusk and long after sunrise. It bites quite as hard as any of the other *Anopheles*, and is as eager to get indoors. At Cape May, which is the only place where I have found it at all abundant, it is the most annoying form and far more troublesome than *C. pipiens*.

DESCRIPTION OF THE LARVA

Does not differ in general appearance from that of *An. punctipennis* and *An. quadrimaculatus*, but a little smaller, ranging from 5.5–6 mm. (.22–.24 inch) in length when full grown. Dirty grayish brown, with usual variation of other larvae. White dorsal stripe may be present in living larvae but no indication in alcoholic specimens. Maculation of vertex variable, much larger than in other species, with much less defined edges. Second joint of antenna shorter, does not taper as much apically as in allied species, very blunt, with two long spines serrated on one edge and six long hairs, which have common center; dark brown, pale yellow at base, surface set with rather long spines; four-branched hair larger and situated one-third length of antenna from base. Mandible and maxillary palpus of normal *Anopheles* form, former with four, instead of three, curved dorsal spines, three of them feathered on one side; latter with two apical spatulate processes. Dorsal plates on each of abdomnial segments large, and circular spots beneath them very obvious. Respiratory apparatus very similar to that of *quadrimaculatus* and *punctipennis*. Lateral combs consist each of large plate, posterior edge with seven or eight long stiff spines, ten or twelve shorter spines between. Ninth segment rather stout, dorsal tufts and ventral fan as in others, with dorsal plate a little larger. Tracheal gills short and stout, less than half length of other two species.

HABITS OF THE EARLY STAGES

The eggs are laid singly on water. The larvae live in ground pools, usually in tidal marshes. Breeding does occur inland, but winged examples are usually taken along the seacoast.

The winter is passed in the adult form in sheltered places.

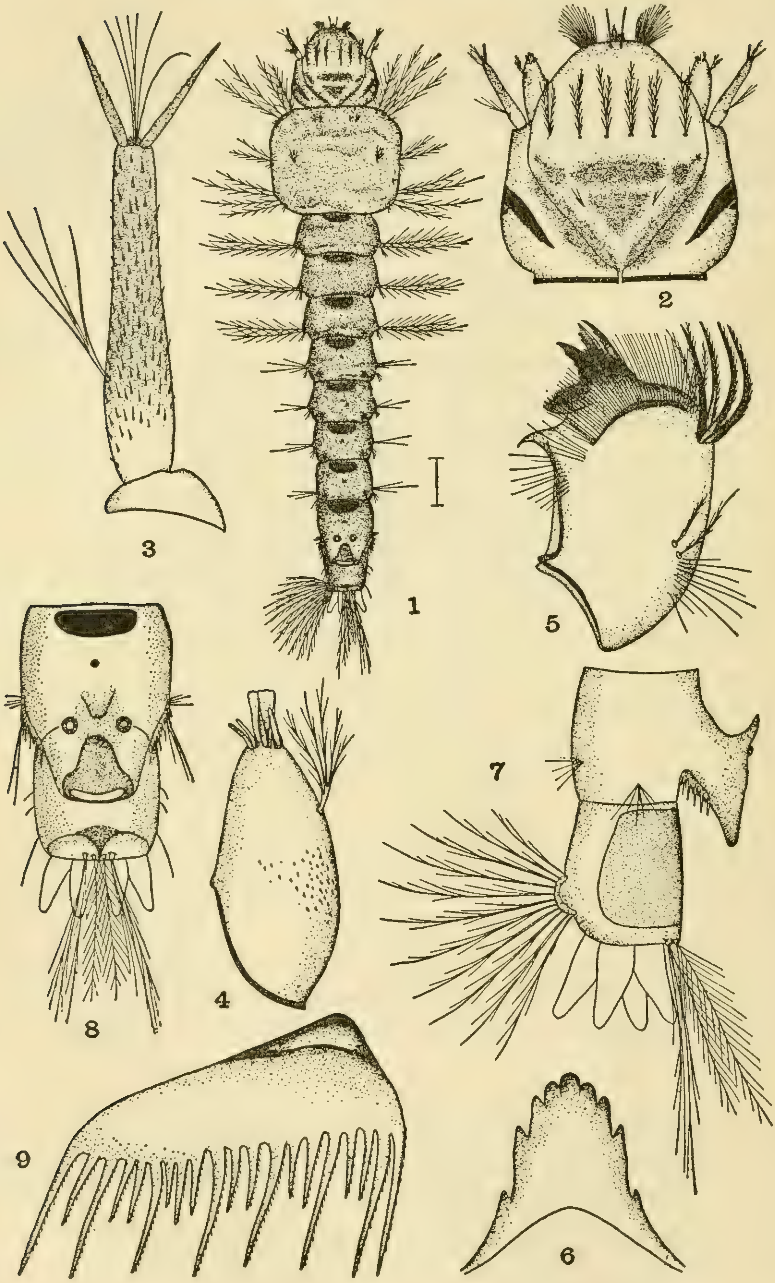


Fig. xix. Larva of daylight Anopheles. *Anopheles crucians* Wied. (After John B. Smith.) 1, larva; 2, head from above; 3, antenna; 4, palpus; 5, mandible; 6, mentum; 7, anal segments from side; 8, anal segments from above showing spiracles; 9, one of the scales (all enlarged).

Culex salinarius Coquillet
The Unbanded Salt Marsh Mosquito

DISTRIBUTION AND CHARACTERIZATION

[United States, east of Great Plains. Trapped 1,850 females in New Jersey.]

This species so like *C. pipiens*, ordinary house or rain barrel mosquito, that description of latter (found on page 64) will apply to this species also. In all structural details save tip of female palpi, drawings for the one will answer for other. *C. salinarius*, however, is somewhat slighter, giving legs appearance of unusual length. In female white bands of abdomen narrower and better defined; as a whole, mosquito seems blacker. In long series of adults from various localities lanky and generally darker appearance would form best characters for separation. Specimens a little rubbed or in alcohol, indistinguishable.

HABITS OF THE ADULT

This is the only one of the salt marsh mosquitoes that hibernates in the adult stage and that does not migrate for any considerable distance. It seems much more abundant on the Newark and Elizabeth marshes than it does further south, and at Cape May it was not found until well along in the season. It is a night flier and, on the marshes where *sollicitans* and *cantator* rise up to greet the visitor by day, *salinarius* will not be seen at all. But in the early evening it flies readily and is as greedy for blood as any other of the species. It sings like *pipiens* and has the same tendency to get into houses, though perhaps not so well marked. Hibernating specimens have been found in buildings along the edge of the marshes, and it is quite possible that the insects come up into the edge of the cities even though they fly no further inland. They remain in hibernation until April and continue breeding until October.

Mr. Viereck observed their marriage flight at Cape May on two occasions, just at nightfall. An egg boat is formed as in case of *pipiens* and *territans*, but the aggregation of eggs is smaller in number.

DESCRIPTION OF THE LARVA

When full grown, 6–7 mm. (.24–.28 inch) long, exclusive of anal siphon. When young, wrigglers whitish with tinge of yellow or brown, head and thorax very large in comparison with abdomen. Large larvae translucent, pale yellow or brownish with regions of body proportionate. Head subquadrate, broadest through eyes, about one and one-

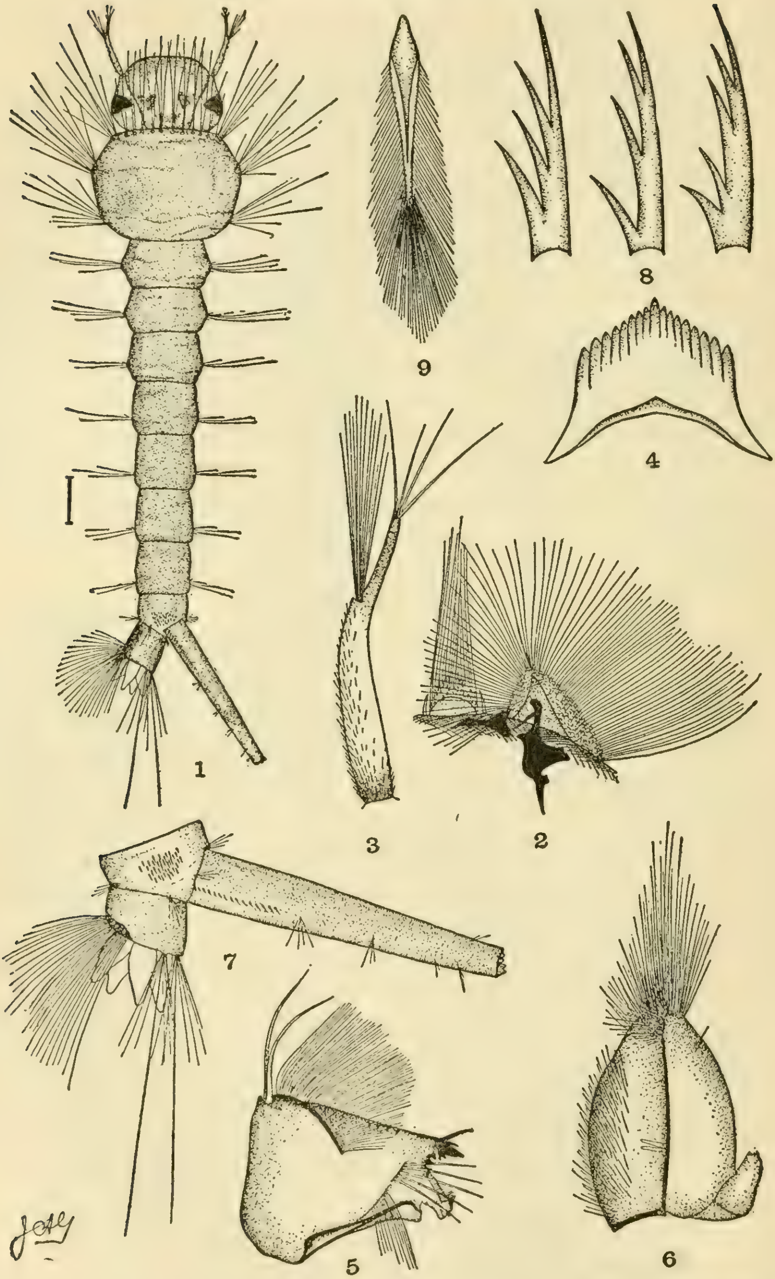


Fig. xx. Larva of unbanded salt marsh mosquito. *Culex salinarius* Coq (After John B. Smith.) 1, larva; 2, mouth brush; 3, antenna; 4, mentum; 5, mandible; 6, palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from eighth abdominal segment (all much enlarged).

half times as long as broad. Prior to last larval stage head larger than thorax, usually immaculate; in last stage, smaller than thorax, more chitinized, with blotches on vertex variously shaped and diffused, but always bisymmetrical. Near anterior part of head four tufts, each composed of four or five hairs, somewhat larger tuft at base of each antenna. Antennae large, long, thickest near base, tapering slightly for two-thirds length, abruptly very narrow to apex, leaving offset upon which large tuft of long hairs extending considerably beyond tip. Apex with three long bristles, a short one, and a small articulated joint. White, except apical third and base; black surface covered with fine hair-like spines. Eyes large, black and occupy broadest part of head. Rotary mouth brushes entirely composed of simple hairs. Mentum pentagonal, with fifteen to twenty-one teeth, always with equal number on each side of apical tooth. Mandible triangular with blunt corners. Maxillary palpus has rather small tuft at apex; surface clothed with patches of hair and basal joint very small. Thorax wider than long, angles very acute in small and half grown larvae. Beside normal lateral hairs, four small tufts of two or three long hairs each, extending forward over head on anterior margin, and several smaller tufts between these and first lateral tuft.

Abdomnial segments from one to six subquadrate, deeply constricted at joints, especially in anterior segments. Two hairs in lateral tuft in all except first and second segments, these with three or four hairs; smaller very fine tuft hairs also on dorsal part of segments near lateral borders. Seventh segment has only short hair tufts. Scales of lateral patches on eighth segment small, from twenty-eight to fifty in each patch irregularly arranged. Single scale has long fringes at sides and apex. Anal siphon long, slender, not concave, evenly tapered, varying in length from five to seven times its width at base. From twelve to eighteen spines in each lateral row, extending about one-third from base, individual spines broad and light colored, with three or four teeth each; small short tuft terminates each row, several smaller ones toward apex. Ninth segment slightly longer than broad, with hairs in ventral row of tufts rather short, double dorsal tuft mostly with very long hairs.

HABITS OF THE EARLY STAGES

Egg boats of this species seem to disintegrate rapidly and are rarely found. The larvae occur everywhere on the marsh in salt as well as fresh water, but as a rule they are more abundant along the edges of the highland than nearer the shore. No specimens have been collected prior to the last days of May, though as they were then two-thirds grown, it is probable that the middle of May is about the date of their first appearance. They increase in numbers as the season advances and continue until late October. Ordinarily they are found in tolerably clean water and when in company with the stumpy-tailed wrigglers of the other marsh species, they are readily recognized.

HOUSEHOLD GROUP

[The notable members of the household group are *Culex pipiens* and *Culex territans*. Members of these species pass the winter in the adult form in sheltered places. They lay their eggs in boat-like masses on the surface of either fresh or polluted water. Their flight range is limited, two and one-half miles being the greatest distance accurately recorded for *pipiens*, and that only when breeding intensively over a large area.]

Culex pipiens Linnaeus

The House Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northern hemisphere, but not in extreme north; in North America, the northern Atlantic Coast region, westward through Illinois; in Europe and probably temperate Asia. Trapped 323,041 females in New Jersey.]

Small or medium; brown or yellowish, rather narrow, but well defined white bands at base of abdominal segments; legs and beak unbanded, wings unspotted.

DESCRIPTION OF THE ADULT

Medium size, though small individuals common. Ranges from 4–5½ mm. (.16–.22 inch) long, exclusive of beak, which is about half length of body. Wings expand 7–10 mm., according to size of insect. Head behind large black eyes brown, with few yellowish scales, distinct yellow border to eyes; beak brown, darker toward apex, somewhat thicker and shorter in male than female. Palpi in female fuscous grayish at extreme apex, apparently three-jointed, the terminal one pointed and wholly retracted within third joint; antennae dark brown. In male antennae ochraceous brown, palpi same color, whitish beneath at bases of two apical joints; as in *Theobaldia melanurus* not dilated, but two terminal joints comparatively much longer; basal joint shorter.

Thorax brown, many golden brown scales scattered over surface. When partially denuded, ridged, giving impression of dusky longitudinal lines.

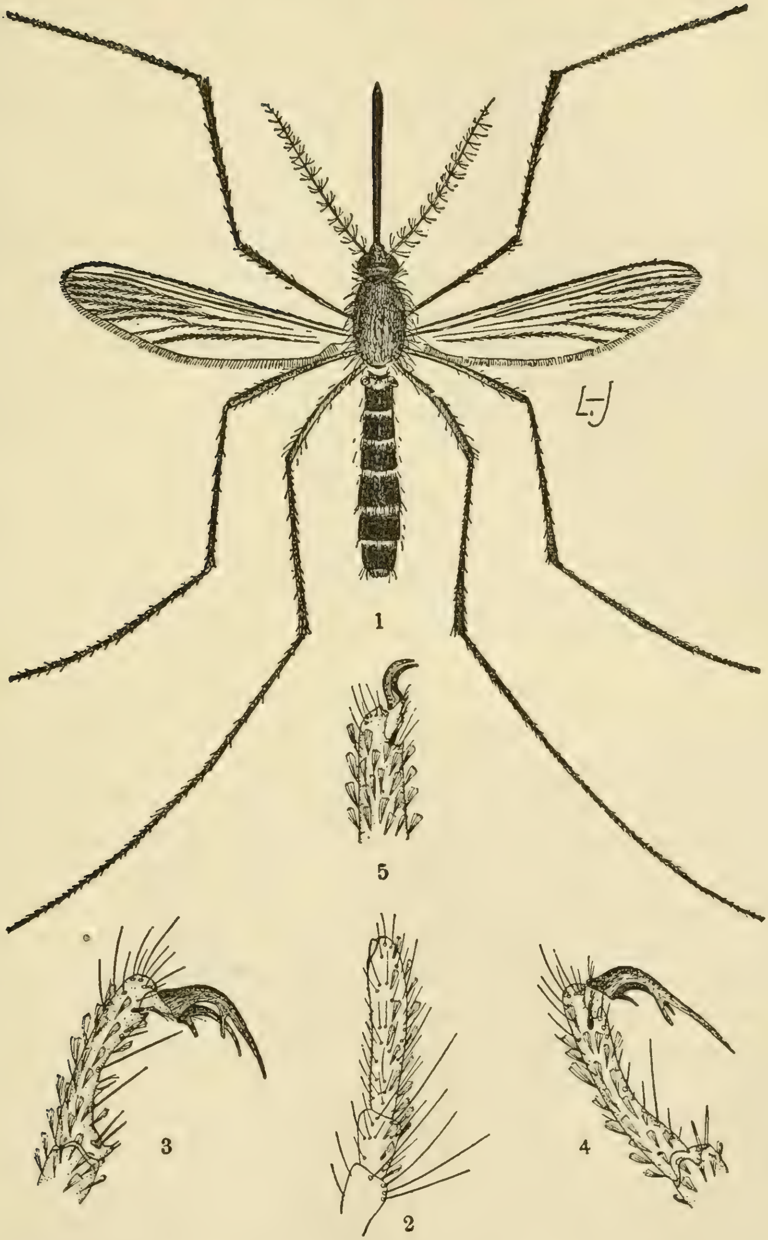


Fig. xxi. Adult house mosquito. *Culex pipiens* Linn. (After John B. Smith.) 1, adult female; 2, palpus of same; 3, anterior, 4, middle and 5, posterior claws of male (all enlarged).

Femora brown, becoming darker distally until, at apex, distinct white spot; pale yellow beneath. Tibiae dark brown, paler beneath, with ochraceous spot at extreme apex. Tarsi blackish brown entire length. Claws of anterior and mid-tarsal joints of male one-toothed, the longer with median tooth, shorter with basal tooth. Posterior claws of male and all those of female simple, of equal length and sharply curved.

Abdomen blackish brown, with yellowish, moderate or narrow bands at the base of segments. In female, bands narrower laterally and well defined, especially in anterior segments. In male, become very wide close to lateral borders, apical segment often wholly yellowish. Not so well defined in male as in female. Beneath abdomen yellowish brown.

Range of size variation considerable, in color very decided. In pines of South Jersey specimens often almost rusty red, large, suggesting different species. Late in season small, almost blackish form at New Brunswick; equally as vicious as larger forms. This mosquito best distinguished by having no peculiar characters. It is just the common every day brown mosquito that gets into our rooms and bothers us at night. If it has any peculiarity at all it is that it usually has a leaner and more hungry appearance than most.

HABITS OF THE ADULT

The term "house mosquito" is expressive of the most objectionable habit of the species—its persistent effort to get indoors. Other species of *Culex* will get into houses through open doors or windows, or on the clothing of persons coming in; but *pipiens* actually works its way in through crevices, around windows and even through screens. It comes indoors because it wants to and not necessarily in search of food. This is the species for which the term *pungens* is employed in some earlier writings. Recent study has developed the fact that our species is identical with the common European species and the older name takes priority. Dr. Howard has, indeed suggested that this may be an importation from some European country.

It winters in the adult stage, and almost any place will serve, provided it is dark and sheltered from direct winds. Barns, cellars, and the ordinary outbuildings are favorite localities. Hibernation begins long before breeding ends and some specimens of the early September developments go into retreat, to be joined by ever-increasing numbers from every succeeding brood. It has been indicated that only females hibernate, and these are impregnated before retiring; but they take no food, depending upon the stored products accumulated in the larval stage.

In the spring when warm weather has set in definitely these females make their way out, seek food and lay the eggs as soon as they are developed. No ovarian growth takes place in the hibernating specimens while they remain in winter quarters.

When the eggs are developed, which is rarely until late in May, they are laid in the nearest suitable place, any place where there is water. The female oviposits at night or in the very early morning and from the description of an eye witness she rests on the surface with her legs extended, extrudes an egg from the ovipositor and places its broad end down on the surface, resting against the hind tarsi. The next egg is set against the one previously laid, and as it is coated with a sticky substance it adheres to it at once. And so egg after egg is placed until the boat is completed. When laid the eggs are nearly white, but they usually turn normally dark gray or brownish before morning. About 400 eggs are laid by one female, in one boat if she is undisturbed, in two or more if she is interrupted.

It usually requires only twenty-four hours or thereabout for the larva to develop within the egg and hatch. Hatching usually takes place at night, the little wriggler slipping out of the bottom of the egg directly into the water.

When the adults emerge during the summer the males usually appear a day or two before the females, and copulation takes place during flight in the early evening soon after the females have emerged. The eggs develop rapidly, and in a very few days after assuming the adult form this summer mosquito is ready to oviposit.

This *Culex pipiens* is not a migratory form and usually flies no further than is necessary to secure food and a suitable place to lay eggs. Blood food is not necessary for this species to mature ova.

As to the bite it is not as painful as that of *sollicitans* or *cantator*, but it is apt to be more lasting. It feels somewhat as if the lancets were finer and more penetrating. *Pipiens* has the singing habit in an aggravated form and will hover a long time before deciding upon a satisfactory place to settle. This singing is actually more annoying to many people than the bite itself, and the sound when it begins just as sleep approaches, compels attention and effectually awakens the victim.

The number of broods is indefinite and depends altogether upon breeding possibilities. In my pails I have at almost all times all stages from egg to pupa, and the same condition may usually be found in any of the more permanent pools. In a rain water puddle, however, all the larvae will be of about one size.

The species occurs throughout the state, more or less abundantly, as opportunities for breeding present themselves. Some localities that are usually quite free may, after a week or two of showery weather, become seriously infested.

Next to the salt marsh species this is the most offensive mosquito in the state; in many parts of the state it is the *only* troublesome species.

DESCRIPTION OF THE LARVA

When full grown, 7–8 mm. (.28–.32 inch) long, exclusive of anal siphon. Very transparent, pale yellowish and usually attains faint shade of color of food eaten. Newly hatched and medium sized larvae almost white except for food matter in alimentary canal, and yellowish tinge to head and anal siphon. Head transversely elliptical, full at sides and pale fuscous in color; maculation on vertex slight, consists of central spot and two oblong marks at sides, more or less diffused. Six tufts of four or five moderately long hairs, each on dorsal part, lateral ones near base of antennae. Antennae only slightly curved, completely obscured by tuft of twenty or more long hairs arising from sharp offset at outer two-thirds. Surface covered with short, spiny hairs; apex has three long bristles, a short one, and a small joint. Eyes large, two distinct forms—one blunt at vertex, another drawn into acute angle. Hairs of rotary mouth brushes simple. Mentum pentagonal, with nine or eleven teeth on each side of apex; some variation, chiefly in length from base to apex, and consequent slope of sides. For mandible see Fig. XXII. Maxillary palpus oval with a long apical tuft and patches of short hair on surface. Basal joint small, crowned with small spines at apex.

Thorax in full grown larvae rounder, broader than long, scarcely any angulations. In central part of anterior margin two tufts long hair extend forward over head; between these and lateral tufts another smaller one. Few single hairs of first lateral tuft also encroach upon anterior margin. In small larvae thorax not so robust; lateral angles much better marked. Abdominal segments from one to seven have lateral tufts of two hairs each, except two anterior, which have four or five hairs each; pairs of smaller and finer hairs scattered over dorsal surface. Eighth segment has lateral patches of from thirty-five to forty small scales. Individual scales with long fringes at sides and apex. Anal siphon pale brown, about four times as long as broad, tapered on terminal half. Two rows of spines from twelve to fifteen in each series; number of hairs arranged in pairs. Single spines pale brown, broad at base, with three or four long teeth. Ninth segment completely covered with chitinized saddle; double dorsal tuft of long hairs only. Ventral

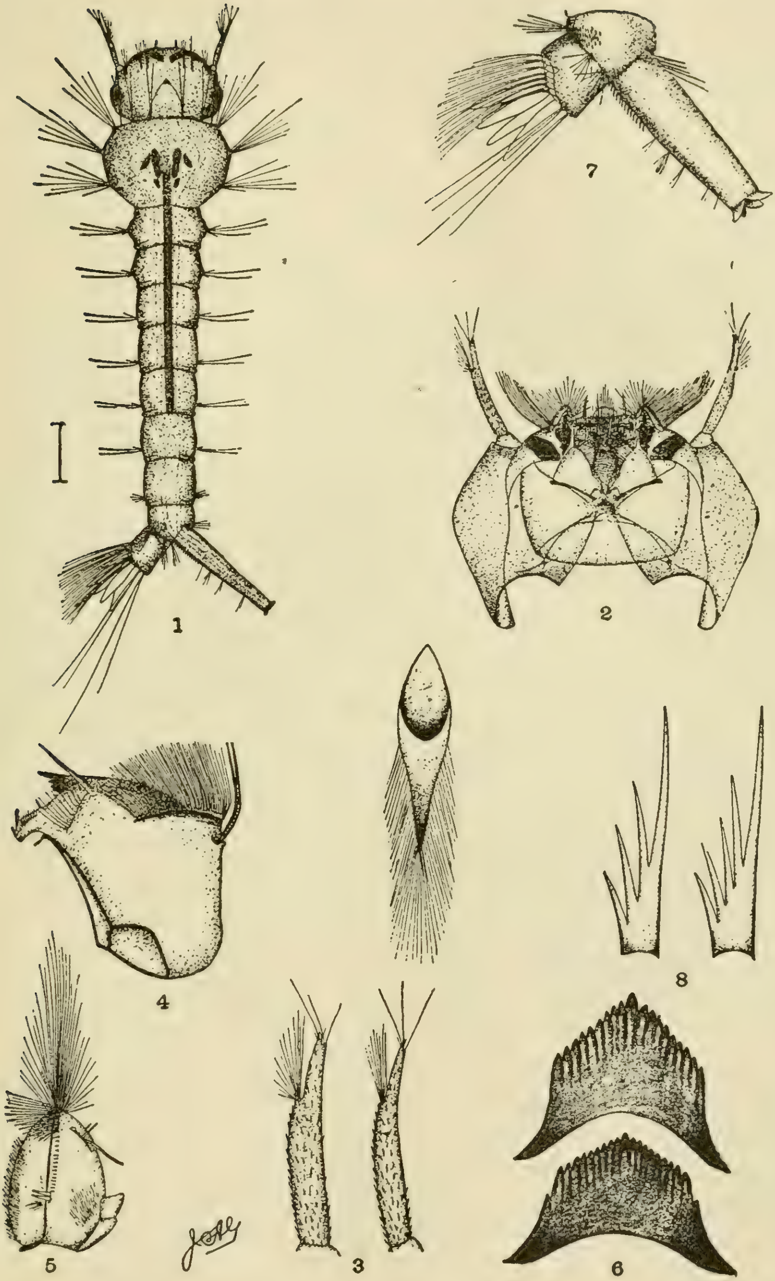


Fig. xxii. Larva of house mosquito. *Culex pipiens* Linn. (After John B. Smith.) 1, larva; 2, head below; 3, antenna; 4, mandible; 5, palpus; 6, mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, single scale from eighth abdominal segment (all enlarged).

row of tufts normal, confined to barred area. Anal gills longer than ninth segment and rather stout. Larva varies slightly in length of anal siphon and anal gills.

HABITS OF THE EARLY STAGES

This larva may be found almost anywhere in stagnant water. Anything will answer, from a tin can half full of rain water to a sewer basin, cesspool, manure pit, pool of rain water that lasts eight or ten days, bucket, tub or other receptacle left outdoors, rain barrel, or even a watering trough that is rarely emptied. In cities and towns sewer basins, neglected sunken lots in which water accumulates, ditches along roads when allowed to become overgrown and choked—all are prolific sources of supply. And they will breed indoors as well as out if given a chance. I have found a brood in a battery jar left half filled with water in the laboratory, and have seen wrigglers in the concave floor below a shower bath which had become filled because of a plug in the waste pipe. In one of the leading seashore resorts many of the large hotels have a space from two to six feet below the basement floor in which pools form from surface drainage, and in these pools larvae develop in countless numbers. They find their way through the elevator shafts into the house and throughout the rooms, to the great discomfort of the guests. I found that I could leave my windows open safely at night, if only I closed the fanlight into the hall. It is this ability to develop almost anywhere that makes *Culex pipiens* our most common and widely distributed species.

After hatching from the egg as already described, the larva requires from six to eight days to attain full growth, six the minimum period in midsummer when food is plentiful, eight the more usual period. When weather is cold and water clean it requires a longer period and resulting adults tend to become dwarfed, as they do when a pool dries up so fast as to crowd the insects and force them into the pupal stage.

In the pupal stage the insects remain for two or three days, sometimes longer if the weather be cold. Rarely the entire development from egg to adult is crowded into one week.

Larvae are rarely found until well along in May, and then only in comparatively small numbers. During July and August swarms of larvae may be found in any suitable place. They continue in decreasing numbers after September until hard frost. I have found some of them under quarter-inch ice in November and bred adults from them.

This larva is typical in habit, entirely dependent upon the outer air for its supply of oxygen, and succumbs readily to any oily covering of its breeding place.

PLATE III. TOP. A mosquito-breeding pool on an undiked salt marsh periodically flooded by high tides. BOTTOM. Close-up view of small salt-marsh pool showing concentration of larvae and pupae of the salt-marsh mosquito.

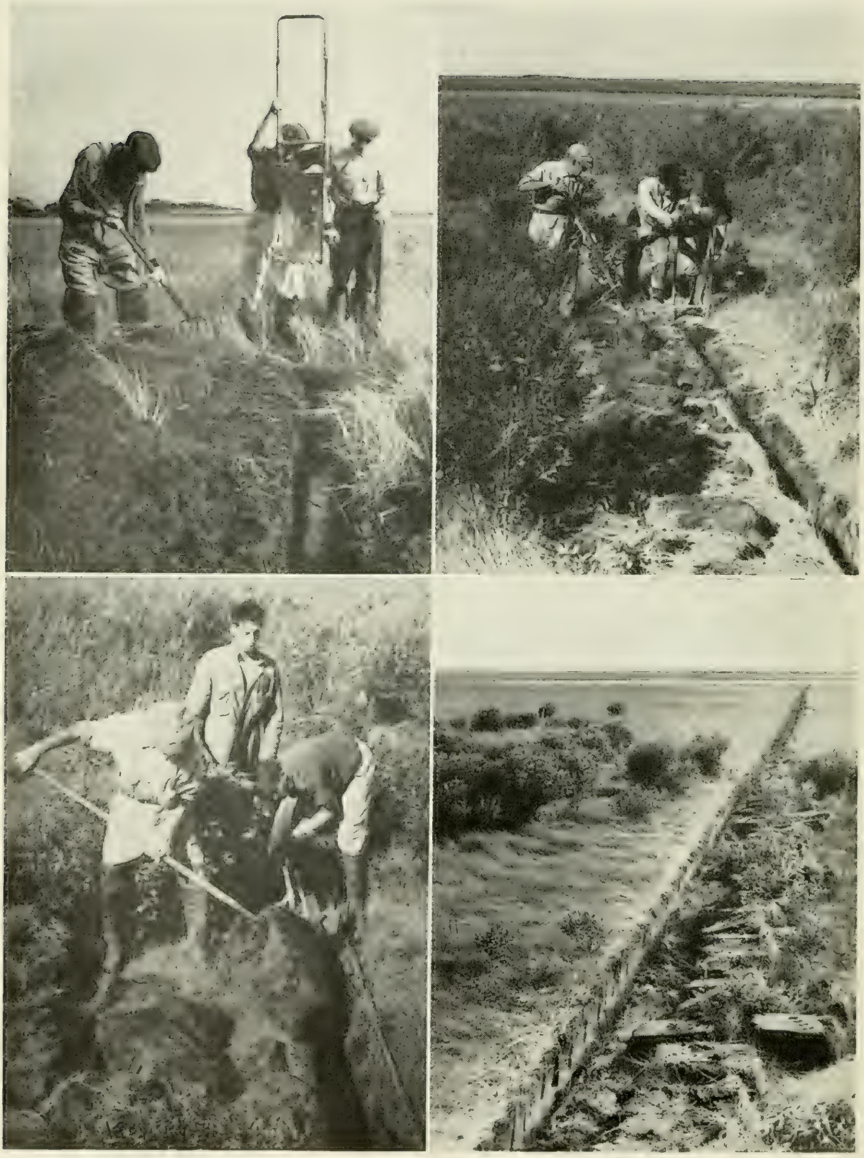


PLATE IV. This special three-man, salt marsh ditching spade weighs thirty pounds, is U-shaped with cutting blades on three sides. It cuts a complete sod the full depth of the ditch in each cycle of operation. TOP LEFT. The first step is to raise the spade high, then plunge it deep into the marsh sod. TOP RIGHT. Operators one and two then step on bars on either side, forcing the blade to the full depth of the ditch. Operators one and two push forward on handle of spade, breaking loose the sod which was partially cut by side blades in original down stroke. BOTTOM LEFT. Operator three pulls sod from spade and stacks it beside ditch. Side blades of spade are shown in this view. BOTTOM RIGHT. The finished ditch, ten inches wide and twenty inches deep, can be cut easily by three operators at the rate of eight hundred feet per day.

[The experience of the last twenty or more years has shown that this species moves several miles from its breeding place, but that such movements take place only where intense broods are thrown off from very large breeding places.]

Culex territans Walker

The White-Dotted Mosquito

DISTRIBUTION AND CHARACTERIZATION

[North America, east of the plains. Trapped 565 females in New Jersey.]

It is closely related to *pipiens* in structure and habits; without aid of lens no differences can be observed. Distinguished by thorax, which has two or four small white spots on upper surface and sometimes inverted U-shaped mark near base.

DESCRIPTION OF THE ADULT

Runs about size of *C. pipiens*, though usually smaller. Head brown, scattered yellow scales, yellow border to eyes. Proboscis, antennae and palpi of male fuscous; palpi whitish beneath at bases of apical joints. In female palpi dark brown, grayish at apex; fourth joint shorter and retracted; antennae and proboscis also dark brown.

Thorax brown; many scattered yellow scales over surface; two or three equally spaced stripes of black bristles down center. Two white spots on middle of dorsum almost always present; two other patches of white often situated more laterally and posterior of spots; inverted U broken at middle, near base. Femora and tibiae brown, lighter beneath and at basal part of femora; knees distinctly white and tarsi blackish throughout. Claws same as in *C. pipiens;* anterior and middle unequal, one-toothed, posterior and all those of female equal and simple.

Abdomen blackish brown, with pale yellowish bands narrow in female and broader in male.

HABITS OF THE ADULT

So far as the adult is concerned everything that has been said of *pipiens* applies to this form as well. It seems to occur throughout the state, but is not quite so common as *pipiens*. When specimens are rubbed or have been in alcohol, there is no way of determining them positively as distinct from *pipiens*.

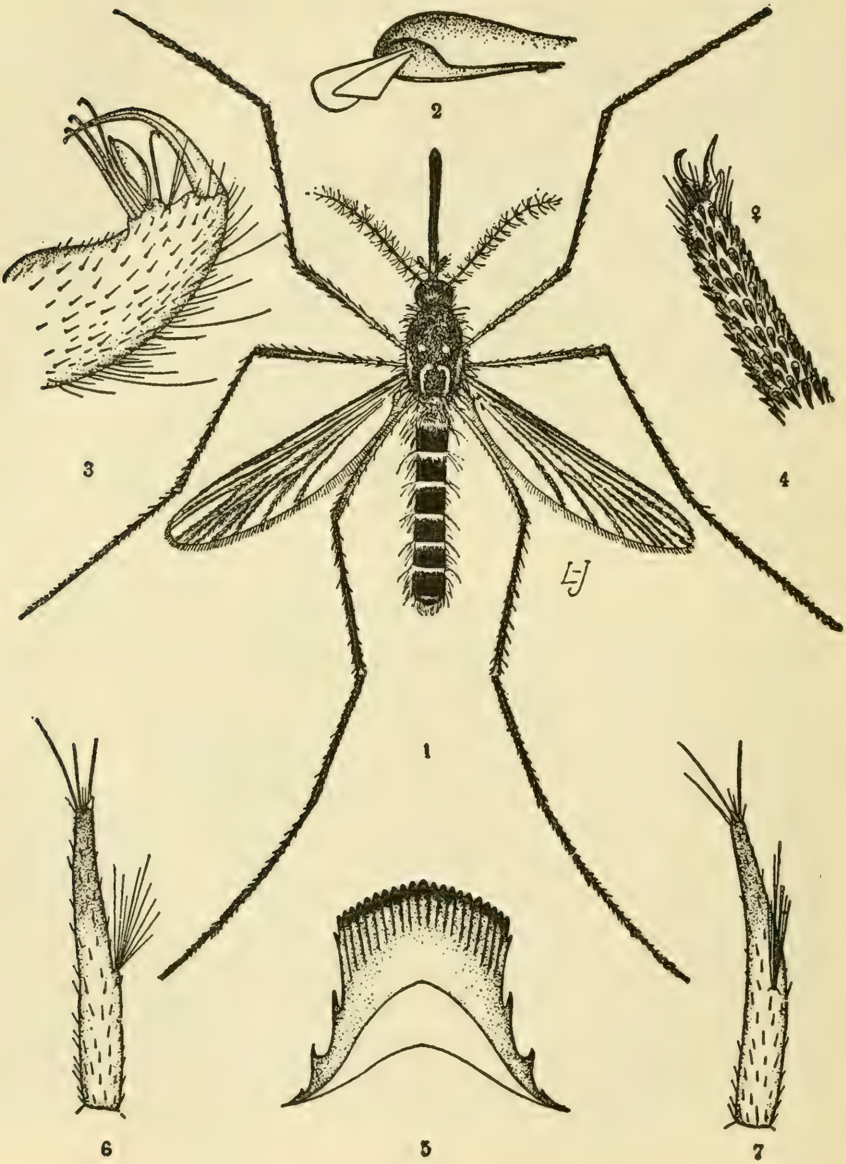


FIG. XXIII. Adult of white-dotted mosquito. *Culex territans* Walk. (After John B. Smith.) 1, adult female; 2, appendage to tip of clasper; 3, clasper of male genitalia; 4, anterior claws of female; 5, mentum of larva; 6, 7, antennae of same (all enlarged).

DESCRIPTION OF THE LARVA

Resembles *Culex pipiens* so closely that the figure on page 69 serves for both species; differs from *C. pipiens* as follows: Antenna pale brown, whitish at basal half with tuft well below middle; hairs composing tuft shorter, only ten to fifteen in number, situated on comparatively small offset. Surface covered with hairlike spines; apex with one long and two shorter spines, few short hairs and small joint. Mentum peculiarly shaped, almost square, rounded at apical margin and excavated inwardly at base. Each side has three or four teeth, central ones largest; anterior margin has from seventeen to twenty-three small, evenly shaped teeth. Anal siphon similar to that of *C. pipiens*, both species varying in length somewhat; but a few more spines to lateral row in *territans*. Anal gills long, not pointed, with circular spots scattered over surface.

HABITS OF THE EARLY STAGES

Eggs appear as in *pipiens*. In general appearance and habits the larvae are also similar; but *territans* is not found in really foul water, in my experience. In life the two species are readily discriminated by the antennae, which are always prominently spread out, so that the position of the tuft is readily noted. The wrigglers occur in the pails quite as early as those of *pipiens*, as late as October.

FRESH WATER SWAMP GROUP

[The notable members of the fresh water swamp group are *Aëdes vexans* and *Mansonia perturbans*. *Vexans* passes the winter as an egg in depressions in upland soil; *perturbans* winters as a larva fastened to the roots of aquatic plants in soft bottomed ponds and swamps. *Vexans* lays her eggs on moist mud in depressions or on the edges of fresh water pools, *perturbans* lays them in star-shaped groups on the surface of the water. *Vexans* has a determined flight range of at least fifteen miles, while *perturbans* has also been traced for fifteen miles.]

Aëdes vexans Meigen

The Swamp Mosquito

DISTRIBUTION AND CHARACTERIZATION

[North America from Canada to northern Mexico. Trapped 286,314 females in New Jersey.]

Medium sized or small, tarsi narrowly white-ringed at base of joints; beak unbanded, wings unspotted. Abdominal segments have bands of pure white at base, constricted in center and narrowed at sides.

DESCRIPTION OF THE ADULT

Medium or small, ranging from 4–5.5 mm. (.16–.22 inch) long, excluding beak, which is about half length of body. Head back of large black eyes golden brown, small lateral patches of black and white scales; proboscis dark brown, black toward tip, without markings; palpi in female normal, dark brown, white at apex, with very small fourth joint, somewhat flattened and retracted. Male palpi similar to *A. canadensis*, but stouter, blackish brown, with white band in center of basal joint and another, rather broad white band at base of two terminal joints. Fan-like tufts normal size; central joint extends one-third its length beyond tip of beak. Antennae brown in both sexes, that of female yellow at basal two or three joints.

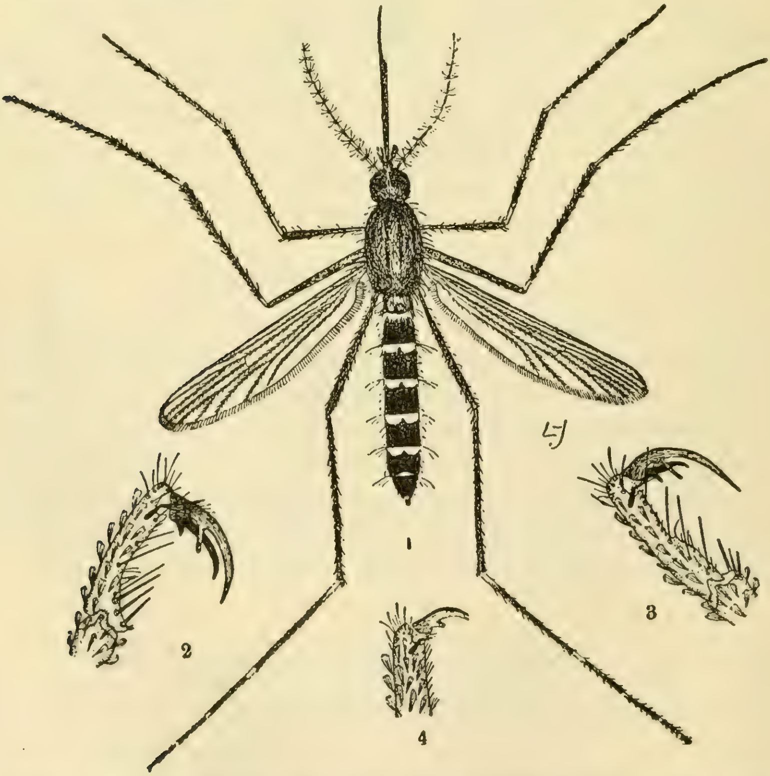


FIG. XXIV. Adult of swamp mosquito. *Aëdes vexans* Meig. (After John B. Smith.) 1, female adult; 2, anterior; 3, middle and 4, posterior claws of male (all much enlarged).

Thorax dark brown, with many golden yellow scales evenly scattered over surface; pleura paler brown, with few small patches of white scales. Femora and tibiae deep brown, yellowish beneath; base of femora and knee spots also yellowish; tarsi brownish black, with very narrow whitish rings at base of all joints, except the last in front and middle legs. Claws of male in anterior and middle tarsal joints unequal in size, larger with long median tooth, smaller with short basal tooth; posterior claws equal, each with median tooth nearer base. In female claws alike on all feet, equal and with single tooth, as in male posterior feet.

Abdomen in female dark brown, with band at base of segments constricted in center and toward sides, where it joins lateral markings, which extend upward from venter, so as to appear as two lunules placed side by side. Penultimate segment has, in addition to basal band, narrow apical one, slightly prolonged forward in middle; last segment with small apical band only. In male banding similar, but bands almost or wholly divided in center and join the side markings without lateral constrictions. Abdomen creamy white beneath, with incomplete brown apical bands.

HABITS OF THE ADULT

This is one of the species that delights in porches and gardens and does its share toward the end of the season in making life miserable. It will get through an open door or window, but will not attempt to crawl through screens or work through crevices. It bites readily, but not very viciously, the results being less painful than from either *pipiens* or the salt marsh species. It is small, black, with narrowly white-banded legs and banded abdomen. The abdominal bands, being constricted and almost divided in the middle, form one of the most certain means of recognizing the species. There is considerable variation in size, it looks smaller and chunkier than either *pipiens*, *cantator*, or *sollicitans*. When rubbed, a large specimen is sometimes very like *cantator* in appearance.

It occurs throughout the state and season, though early in the year it is found only in small numbers, and is rarely troublesome in towns or about houses. Later, in August and early September, it is often the dominant species, even close to or at the shore. Mr. Viereck reports it as one of the troublesome species on porches at Cape May, and further inland it replaces the salt marsh forms as an extraterritorial species. Although not a migrant like *sollicitans* or *cantator*, nevertheless *vexans* is not a strictly local pest and often appears a considerable distance from any known or possible breeding place. A mile or two is an easy proposition for the species and five miles is not outside of its possibilities. It seems, however, to move as an individual rather than in considerable bodies and the increase in numbers is gradual; there is no sudden appearance of a swarm overnight. So the disappearance is equally gradual, isolated specimens remaining in town until early October and in the field much later.

The adults die off gradually as winter advances and hibernation is in the egg stage. The eggs are deposited singly on the surface of the water and sink to the bottom, or they may be placed at the edge of a low pool or in the moist mud of a depression from which the water has evaporated. The length of adult life is probably considerable, but no definite experiments were made and the period of nearly three months is based upon field observations only. At all events it is not a brief one and is reckoned by weeks rather than days.

DESCRIPTION OF THE LARVA

Larva varies greatly in size, measuring from 6–8.5 mm. (.24–.34 inch), exclusive of anal siphon. Figures opposite drawn from large sized larva. Full grown specimens yellowish or grayish throughout, but when young almost white, except head, which is yellow. Head is broadest immediately below eyes, tapers anteriorly and is rounded in front. Six small hair tufts of four or five hairs each on anterior of vertex; one at base of each antenna, others more central, one pair to rear of other. Maculation of head varies immensely, though always symmetrical; Fig. XXV shows some of forms, all common and may be present in a single lot. By far the commonest form, however, is that shown in the Fig. XXV; defined brown patch in center of anterior part of vertex and another smaller in center or posterior part of vertex, on a yellow ground color. Entire lots often have this form of maculation; as there are no other species with similar markings, it usually identifies larva. In young and half grown larvae heads wholly pale yellow, save for slight mark in center. Antenna rather short, curved, thickest at base, tapering apically; surface set with stout spines, color yellow, becoming darker toward apex. The apex has one long and one short spine, two bristles and a small joint. Tuft situated on shaft one-third from base; consists of six or eight hairs. Rotary mouth brushes dense, orange colored, have hairs pectinated in more central part. Mentum triangular, with from twelve to fourteen small teeth on each side of apex. Mandible and maxillary palpus normal, latter with stout basal joint not shown in drawing.

Thorax broader than long, angulated at sides, with rather small-sized tufts arising from angles.

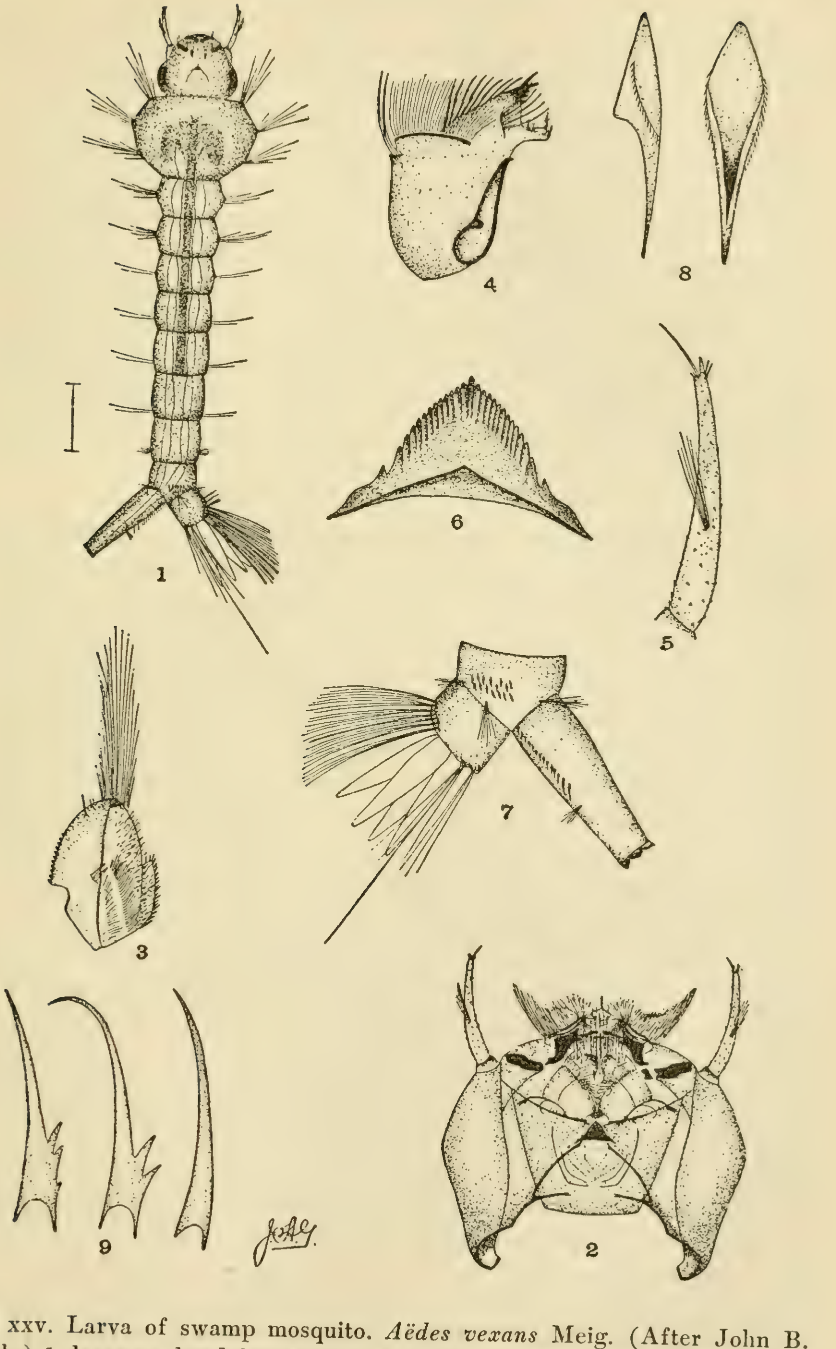


Fig. xxv. Larva of swamp mosquito. *Aëdes vexans* Meig. (After John B. Smith.) 1, larva; 2, head from below; 3, palpus; 4, mandible; 5, antenna; 6, mentum; 7, terminal joints and siphon; 8, single scales from below and side; 9, siphonal spines showing variation (all much enlarged).

Abdominal segments have lateral tufts of hair, four or five in each in two anterior segments, two each in succeeding ones, seventh with short tufts only. Eighth segment has lateral patches of scales, about ten or twelve in each, though may be as many as fifteen, arranged in irregular double row; single scale rather broad, pointed at apex; fringed at sides with fine, short hair. Anal siphon dirty yellow, two and one-half to three times as long as broad at base, lateral rows of spines consist each of from fourteen to eighteen spines extending half length of siphon from base, terminal two separated from rest and from each other. Individual spines usually two- or three-toothed, but occasionally one-toothed or even simple. Ninth segment almost square, not quite ringed by saddle; double dorsal tuft and ventral brush normal, latter with several small tufts below barred area. Anal gills about twice as long as ninth segment.

HABITS OF THE EARLY STAGES

Larvae of this species occur almost everywhere except on the salt marshes or in positively foul water. They are common in woodland pools, though second to *canadensis* there, and are dominant in open swamp areas. In the Passaic Valley, specimens appear in early April and in the Great Piece meadow every pool will be found loaded with larvae at almost all times. The eggs do not seem to hatch evenly in spring, and young larvae will be found when there are already pupae in the same pool. So, not all the eggs laid by one female seem to hatch during the same season or at one time. Some may lie over until next year, but the majority hatch, because there is a steady increase in number with each brood. Just how many broods there may be in one season depends on weather conditions. As early as May 9, a plentiful supply of adults was found in the Garret Mountains, near Paterson, and large larvae in the pools. May 21, there was a young brood in the pools in the Great Piece meadows and in early June, broods were found in the woodland pools along the Whippany River near Morristown, and in the Orange Mountains. Late in June full grown larvae were in the pools on the Preakness Mountain, near Paterson, and before July 1 the adults were out in force. In the Black River Swamp they were found in the same condition at about the same time and so, on June 30, mostly pupae were found in woodland pools on the borders of Spring Lake, near Trenton. July 21, there was a young brood in the pools surrounding Lake Hopatcong, and a few days later mature larvae and pupae were taken everywhere in pools in the Hackensack Valley. The entire Passaic and Hackensack Valleys were kept under observation during 1903, as were also those large swamp areas in Essex and Morris Counties, and always *vexans* was the dominant species. Captures of adults sent in from this territory always showed *vexans* present, and that species breeding in a swamp area at Vailsburgh, became common in the sendings of adults from Montclair and South Orange.

From the Delaware region the open marsh areas almost always turned out *vexans* in numbers. This is, therefore, essentially a swamp species, but it does not occur in deep or dark swamps. It was never found in the huckleberry swamps of Lahaway, nor in my cranberry swamp collections.

By far the greatest number of larvae were taken in permanent water areas, but many of the woodland pools in which it occurred were temporary in the sense that they usually dried out before the summer was over. It was never sent in from gutters or lot rain pools or from foul waters at any time. It was once found in a barrel at Cold Spring, Cape May County. In New Brunswick a brood was found in a lot pool August 12, larvae being mature and pupae already present; a second brood was found September 23 in a similar stage, and there may have been a brood in the interval. This is a low springy place, which rarely dries out entirely and which fills readily with even a light rain. The latest collections of larvae were made during the early days of October, adults emerging about the middle of the month.

Habits of the larvae offer nothing peculiar. Dependent upon atmospheric air they are readily destroyed by any of the oil coverings. The pupal stage varies in length according to temperature, but is usually short—two or three days during the summer.

It is not so readily controlled as the house mosquito, and sometimes causes trouble in jurisdictions outside of those in which it breeds.

[The eggs appear to be laid on moist soil in depressions in the soil and there is some, but not conclusive, evidence that they are sometimes laid on water. Hatching of some, but not all, of the eggs takes place when covered with water. Sods brought into a screened insectary and covered with water showed repeated hatchings the first season and some hatching each of the two subsequent years. Since no opportunity was afforded for reinfestation, the conclusion follows that the original supply of eggs was the source of all hatching in the three years.]

Mansonia perturbans Walker

The Irritating Mosquito

DISTRIBUTION AND CHARACTERIZATION

[North America from Canada to Florida and westward in the timbered country to British Columbia. Trapped 23,730 females in New Jersey.]

Another large species, with tarsi broadly white-banded at base of joints and ring of same color in center of first joint. Beak white-ringed in center and abdomen with indistinct, narrow bands of white at base of segments. General brown color and large size, together with exceptionally broad bands of legs, make it very conspicuous and easily recognizable.

DESCRIPTION OF THE ADULT

Large, brown, measuring from 5.5–6.5 mm. (.22–.26 inch) long, exclusive of beak, which is 2.5 mm. long. Head brown, with numerous creamy scales over surface, extending between eyes; and some black scales in posterior part directed backwards. Proboscis dark brown with yellowish central band. Palpi in female normal in shape, deep brown, with some yellowish scales; terminal joint very small, rounded, with three or four long bristles. In male palpi only slightly dilated, first two joints together as long as proboscis, third joint same length as central. Basal joint has mixed black and white scales; terminal two joints blackish, white at bases. Fan-like tufts dark brown. Antennae of both sexes dark brown, plumes of male fuscous.

Thorax chestnut brown, with numerous yellowish scales over surface, often forming irregular stripes. Pleura brown, with very few dirty white scales in small patches. Femora have mixed black and yellow scales, fewer beneath and at base, with black ring near apex and white knee spot. Tibiae of posterior legs dark brown, almost black, with broad white ring short distance from apex and narrow white rings at base; anterior and middle tibiae may have indistinct bands; usually covered with black and whitish scales collected into spots and patches, sometimes forming two or more narrow, broken bands; apices black. Tarsi black, with broad, pure white bands at the base of joints; whitish ring at center of first joint. Claws of anterior and middle tarsal joints of male alike, each with long claw having median and basal tooth, and small simple claw. Posterior claws equal and simple. In female alike on all feet, being equal and simple, like posterior ones of male. Wings hyaline; veins densely clothed with large brown scales.

Abdomen dark brown, with indistinct, yellowish basal bands, sometimes with white spots at sides. Yellowish beneath with brown scales.

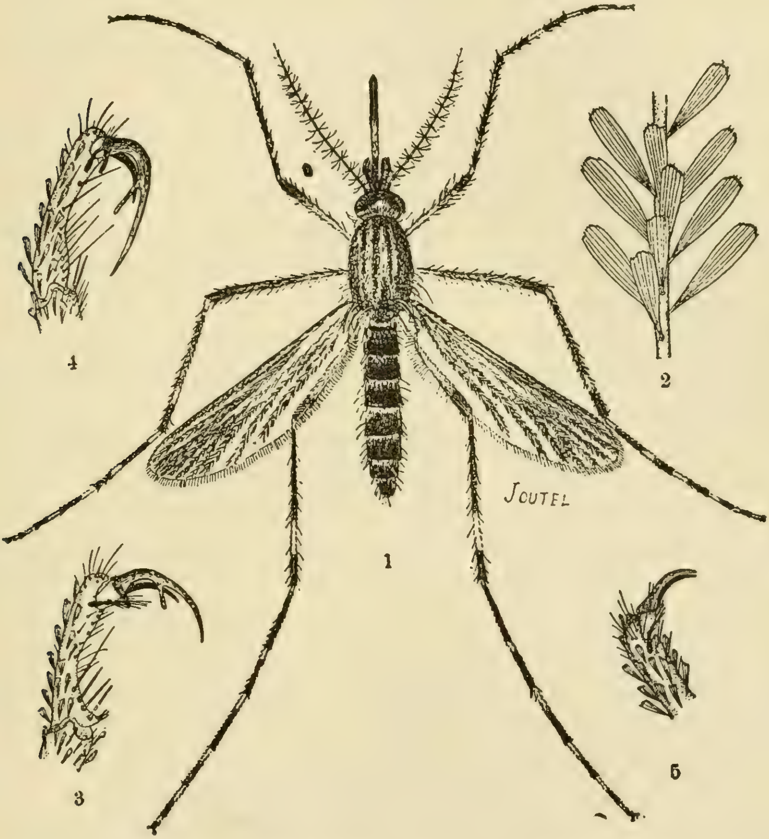


Fig. xxvi. Adult of irritating mosquito. *Mansonia perturbans* Walk. (After John B. Smith.) 1, female adult; 2, part of wing vein showing scales; 3, anterior, 4, middle, and 5, posterior claws of male tarsi (all much enlarged).

HABITS OF THE ADULT

Of the hundreds of examples sent in during 1903 and 1904, between the last days of May and the early days of August, not one showed any traces of developing ova.

Altogether nearly 1,000 examples were examined, large and small, fresh and old specimens, specimens that had fed recently, some that had almost completely digested a meal of blood and some that had apparently never fed at all; but none with eggs in any stage of development and none with the characteristic inflated yet hollow abdomen of the female that has laid her eggs.

The belief that this is a migratory form is based upon the facts that, despite diligent collecting under varying conditions, a male was never found and that they came in under the same conditions and with *cantator* and *sollicitans*. It is not suggested that *perturbans* comes from the marshes; simply that it does not breed on the place and comes in from some outside point.

It is one of the fiercest and hardest biters that we have. As one collector says, "As against *perturbans*, undershirt, pants, and drawers are no protection; they will bite clean through all." Nor are they at all timid or deliberate in the attack; but rather at once dive for the nearest point that offers a chance to make a puncture. They have no scruples about entering houses.

The species sings and where many of them are about, the air is filled with an angry buzz that is quite unlike the preparatory note of any other species known to me.

As to the method of hibernation, nothing is known save that we have never found it as an adult during the winter.

Records indicate a single brood only, with a long life; but the occurrence of a male in late July and of a female with developed ovaries a little later, make this unquestionable.

Fortunately the species is not of serious economic importance, though it is locally common.

Dr. Smith (25) records the discovery of the larva and its habits. He is quoted in considerable detail because of the distinctive feeding habits which distinguish *Mansonia perturbans* from other species.

The breeding habits of *Mansonia perturbans* having been at last discovered, a history of the search in New Jersey may be interesting.

Our first knowledge of the species came from Mr. Brakeley, who, on May 27, 1903, captured about twenty adults. No pains were spared in collecting and noting the habits of the adults and in scouring the numerous water areas at and near Lahaway in an effort to locate the early stages. Fifty to 100 adults were easily taken in the course of a single evening, but not a trace of the larva was discovered anywhere, though the search had been thorough and persistently carried out. At the end of the season's work Mr. Brakeley concluded that they must be migrants from some other place, and this opinion was strengthened by the fact that they appeared at the same time and apparently came in with the salt marsh mosquitoes.

On July 21 of the same year, several females and one male were taken at Lake Hopatcong, and on the twenty-ninth of that month a female with developed ova was caught in the Moonachie woods near Carlstadt.

Other captures in 1903 came from Cape May, July 28, August 11, and September 21; Chester, Morris County, August 9; South Orange, August 26 and Arlington. In none of these places were more than three or four specimens collected.

In 1904 and 1905 not an adult was secured anywhere except at Lahaway, and there they were present in their usual abundance. On June 4, of the later year, a male was among the captures, the second specimen of that sex taken. Search for the larva was continued in these two years, and particular attention was paid to the cedar swamp between Barnegat and Manahawken, where it was supposed that they might breed and migrate to Lahaway. Areas to the south and west of Lahaway were also explored; but in no place was even as much as one adult found. In searching for larvae no body of water was too small or too large to be passed without notice; with a net the surface and the bottom were swept, stones in the water were overturned, taken out and inspected, logs, branches, and limbs of trees were drawn out in the hope of finding them clinging to their surfaces; the bottom material was scooped up and closely scrutinized, weeds and scums were investigated and plant stems were even split open to see whether they contained larvae; in short, everything in the water, animate and inanimate, was examined; but without success.

From the beginning the capture of *perturbans* so far inland as Lake Hopatcong rather opposed the idea that the species bred only along the borders of the salt marsh, and the fact that a male was among those taken, was almost convincing to the contrary. Again, the fact that a male was taken also at Lahaway, pointed toward local breeding, but a decided argument that they did not breed at Lahaway lay in the fact that none of the females taken there showed traces of developing ova—a peculiarity true also of the salt water species that migrate from the marshes. Concerning the habits of the adults Mr. Brakeley says: "They are found all over, in the woods, in the open and on the cranberry bogs and get into one's ears and eyes; they get into the bedroom and into the dining room and at the table they go for the ankles."

In 1906 adults were encountered in some numbers in the Great Piece meadow on August 27, congregated over an acre or two of territory in the center of which was a large pool of water rather thickly overgrown with vegetation. Heretofore this pool had yielded only *Anopheles* and *C. territans;* but now it seemed obvious that it harbored *perturbans* as well. The mosquitoes were most abundant around the edges of the pool and disappeared completely at a distance of 150 feet from it. The most diligent search, however, failed to disclose a single larva of this species —all having apparently reached maturity. From a number of adults which were captured and confined in breeding jars, a single egg boat was secured on September 10. This hatched two days later, but the resulting larvae died a week after emerging, because they had not found the conditions suited to their existence. Yet the pails in which they were kept were provided with earth, stones, decayed wood, and pieces of sod. We had now, however, associated the adults with a particular kind of breeding area, and were able to recall similar water areas at all of the points where adults had been taken. Furthermore, an egg boat could not pass the winter in that stage and if the adults hibernated, Mr. Brakeley would surely have found them in his cellar or barn collecting during the winter; so the only alternative was that they must hibernate as larvae. Therefore, we concluded, that search in the late fall or early spring would most likely secure them. Unfortunately the pool in the Great Piece meadow dried out in the fall of 1906, so the hope of obtaining larvae from that source was destroyed. However, the field of search had narrowed down from the entire area of New Jersey, to small permanent bodies of water with plenty of vegetation.

The first record for 1907 came from Lahaway on June 17, where several adults were taken. Later they were found in large numbers at Trenton, where in evenings spent at "White City Park" from twenty-two to thirty were taken at single sittings between July 30 and August 8. Other adults were taken in small numbers at Grantwood, Westville, Paterson, and New Brunswick. At Springdale and Culver's Lake they occurred very commonly on July 10, in company with the *C. aurifer*, and at Lahaway they were present in such enormous numbers that on one occasion Mr. Brakeley took 300 examples in fifty minutes. These were collected at the corner of a large lily pond just as night was falling. Mr. Brakeley believes that the species is arboreal in the daytime, descending only as dusk comes on, and he bases his belief on the fact that in all his wanderings at Lahaway he has never taken an adult during the day. However, I took a few specimens there on August 1, but the number was as nothing compared with the hordes which are present in the evening. It is interesting to note also that while they appear in swarms only at dusk, they disappear or at least materially decrease in numbers soon after dark and still later fall off almost entirely. At Culver's Lake, Springdale, and in the Great Piece meadows they were common at all times during the day and did not hesitate to bite.

At Lahaway I searched for larvae in certain areas. The first was a small pond about twenty-five by thirty-five feet and from six to thirty inches deep. The central portion was grown over with water lilies, two of the sides were bordered by a solid bank, while the other two were sloped off and supported a thick growth of vegetation in the shallow water. It appeared to be a typical *Anopheles* breeder, and a sweep of the net through the water after these, brought up an egg boat of *Mansonia perturbans.* Thus we had at the very outset discovered at least one of the breeding places of *perturbans.* A few minutes further search, by gently pressing the vegetation beneath the surface of the water, revealed three additional egg boats. We next investigated a larger lily pond on the banks of which Mr. Brakeley had caught his 300 adults in fifty minutes. This was alive with small fish that were able to get to almost every point in the pond; nevertheless, along the shallow borders, I took egg boat number five. A sixth egg boat was taken from a sphagnum pond where we fished for *Corethrella brakeleyi.*

On August first I made a more thorough search of the small pond wherein four boats had been found on the day previous. No part of the water's surface was left unexamined, and in two hours fifty-nine egg boats were collected. All were found for three feet out along the shallow edges, where the vegetation was thickest and of a grassy nature. Along the other two sides the lilies grew close up to the edges, and here and in the center of the pond absolutely nothing was found.

The egg boats were often clustered around a single stalk of grass, forming a star of from four to nine points, one end of the boat being drawn high up along the plant stem by capillary attraction, while the opposite end pointed directly away from the center.

Every part of the pond was searched for larvae as well as egg boats, but with the exception of one young larva, apparently just out of the egg, nothing was found. For a pond of this kind the water was remarkably free from insect or other life. In all, one small fish, three tadpoles, two dragon fly larvae, fifteen small Dytiscid beetles, and one larva of *Uranotaenia sapphirina* were taken from it.

On August 6, an open swamp, six or seven acres in extent, at Trenton adjoining Spring Lake, which was previously suspected of being the source of the *perturbans* supply for the White City Park, was examined for eggs. In such an immense area and with the species so much less common than at Lahaway, the task was not a light one and at the end of half a day's work only twelve boats were collected. Most of these were fragments, found at widely separated places. On August 8 and 12, other parts of this swamp were examined, and eggs were found all over; though in certain spaces where the vegetation was not so thick or in free water, absolutely no traces of any could be seen. In all fifty-seven egg boats, complete or fragmentary, were taken on the Trenton swamp area. On August 8, a larva in the second stage of development was fished up with the bottom material, but continued searching in the same place failed to turn up additional specimens.

All the egg boats collected at Trenton were given up to experimental purposes in an endeavor to bring the resulting young larvae to maturity; but while all were failures it may not be uninteresting to note the various conditions to which they were subjected. First, it was found utterly impossible to carry the egg boats for even a short distance, because unlike those of *pipiens* they sink readily and apparently do not hatch when thus submerged. For this reason the experiments were carried on in a protected place near the swamp itself. A series of five two-quart jars three-fourths filled with water served as breeding places, and on August 8 fifteen boats were equally divided between them. Number one contained only water taken from the swamp; in number two was placed two layers of turf; a third contained one layer of turf and a three-inch layer of vegetable mould from the swamp; in number four was a number of lily stems and in number five an entire plant of arrowleaf. On August 12, the following was noted: number one, eggs not yet hatched; number two, larvae hatched out and all dead; number three, one boat unhatched, others hatched and all larvae dead; number four, no eggs hatched; number five, larvae hatched and dead. Additional egg boats were placed in each, and another jar, number six, was added, which contained grass with all the roots, while in number one was put a seven-inch layer of silt. August 16, the following conditions were noted: number one, an active brood of young larvae, burrowing some three-fourths inch down into the silt where they could be seen in small crevices wriggling vigorously; number two, a lot of young larvae swimming about in the free water—none entering the turf; number three, a large brood of larvae, all dead or nearly so; number four, larvae hatched out and all alive; none attached to lily stems; number five, larvae out and all dead; number six, larvae out and all dead. On August 26, after a period of ten days, I examined all the jars and found everything dead.

After this, experiments were abandoned and it was decided to wait until late fall, to give the larvae a chance to develop, and then to fish the small pond at Lahaway. Meanwhile Mr. Brakeley had been giving the subject some attention, and on September 21, after fishing the pond in vain with his graduate, he pulled up a plant of tear-thumb grass, and from the roots washed out a larva in probably the third stage of development. Two other smaller larvae were secured in the same way, and all were sent to the laboratory. With this information I went down to Trenton on September 27, and with a small net fished the bottom material, where I had previously found eggs. When the water had finally trickled through the cloth, a mass of brown silt was left and in this were two well grown larvae. Others were taken in the same way, but it was not until the bases of the tussocks were swept that larvae were really gotten in some numbers. Collecting was slow, on account of the fact that each sweep of the net would bring with it a mass of partly decomposed vegetable matter and the fine silt would clog the meshes of the cheese cloth net. In all, forty-seven wrigglers were taken in two hours, and they ranged in size from those apparently just out of the egg to those one-fourth of an inch long, and representing stages from one to four. The great majority were of the largest size. No larvae were taken at a depth less than six inches from the surface, and most all at a depth of ten inches and over. Specimens could be gotten as far down as the net could be forced through the matted vegetable roots. Mr. Brakeley, continuing his washings, sent in six larvae on September 26, four on October 1, four more on October 3, and eleven others on October 11. Most of these were small, only three being in the third stage. Collections at Trenton turned up eighty larvae on October 1, 109 on October 3, forty-two on October 9, and forty as late as November 1.

HABITS OF THE LARVA

As before noted, the larva is not dependent upon the outer air for its existence, and, after once leaving the surface from the egg, probably never returns to it until it has assumed the pupal stage and is ready to emerge as an adult for flight in the open air. Unlike the larvae of certain other mosquitoes in New Jersey, which rarely come to the surface, the anal gills are not unusually developed, though they are provided with obvious trachea. It seems that in this case the wrigglers are able to obtain a supply of oxygen through the open cellular tissue of the roots of certain grasses, which they pierce with the curiously shaped air tube that is especially adapted for this purpose. They do not permanently anchor themselves to one spot on the root, but can very readily detach the tube and move to some other place. At the laboratory over 100 larvae were put in a two-gallon jar into which was placed a portion of a tussock around which the larvae were collected in the swamp. In a short time most of them had disappeared within the sod, though a number worked their way through and came out in the crevices on the other side where the sod rested against the glass, giving a splendid opportunity for study. Here they were seen to attach themselves to the grass roots and sometimes remain in the same position for days; but would quickly let go and wriggle away if disturbed. Before piercing the plant tissue the larvae often move along a root, tipping the tube against it as if feeling for a soft spot. After such a performance a favorable spot was usually located in a crotch where a rootlet divided from the main branch.

Just how far the larvae go down into the swamp in winter, if they go down below the point at which they were collected at all, is not known at this time, and how the adult emerges from the pupa in late spring, is also a question which cannot be answered at present.

In collecting at Lahaway, November 10, I found that the heavy rains had raised the July level of the small pond where I found the egg boats over six inches, and that this had resulted in lifting the bottom vegetation so that it floated, leaving about six inches of open water between the bottom of the sod and the mud of the pond bottom. By getting the net through the floating sod and sweeping the root mass underneath, larvae were obtained in every dip; but no larvae were found in the bottom mud. The roots, then, are essential to the larvae and they seem not to occur where none are present. This is also borne out by the observations made by me in the Trenton swamps.

Mansonia perturbans is probably the nastiest of the inland mosquitoes with which we have to deal. It has for its home just those kinds of swamps that are free from other mosquito life, and probably also the shallow borders of lakes which support a heavy vegetable growth. Such places are usually well supplied with predaceous water insects as well as other natural enemies of mosquito larvae and even *Anopheles* is unable to maintain itself to any extent. But *perturbans* selects for its breeding spots so thickly overgrown with vegetation that very few insects and no fish are able to penetrate. Thus the egg boats are left unmolested and the larvae as soon as hatched bore down into the mass of roots away from all ordinary foes. Hard bottomed tussock swamps probably never breed *perturbans*. Such swamps as are apparently bottomless, that is, they are so boggy that solid footing cannot be gotten at any depth, serve as the haunts of the larvae of that species.

Owing to the fact that the larvae are not dependent upon atmospheric air for their supply of oxygen, and that they penetrate silt for some distance, they cannot be reached with the ordinary petroleum oils and lime mixtures. Draining the swamp by means of deep ditches, or the removal or thinning out of the vegetation to give fish and other enemies an opportunity to enter would be the most effective method and, in the long run, the least expensive in eradicating breeding areas. Nevertheless the insects are not altogether beyond our reach as the following experiments, carried on under the direction of Professor Smith, will show.

Experiments with Phinotas Oil. October 7: A small amount of the oil was put into a jar containing about one gallon of water and sixty larvae. It had no immediate effect upon them, but in two or three hours afterwards such as were swimming free in the water were seen to be sluggish in their movements. The next day, about twenty hours after the application, the water and grass sod were examined, and while most were dead three larvae were washed from the sod, which were active and swam freely when changed to fresh water.

An approximately similar amount of the oil was put into a jar containing two gallons of water and 100 larvae. The oil in this case was forced down into the water by means of a pipette and bulb, whereas in the first jar it was put in gently. The material sank to the bottom very slowly and it was fully two hours before it actually enveloped the sod. The next day, twenty hours afterward, only two larvae were alive from the sod; the remainder were dead.

October 10: I went to Trenton and selected a spot in the swamp where larvae were present; six were taken by the first dip of a net and four in the second. Here I staked out an area twelve feet square and from a sprinkling can poured one gallon of Phinotas oil evenly over the surface. The area, as in the whole swamp, is thickly overgrown with vegetation and at this time of the year was worse than in summer because of the dry grass falling down and forming a layer over the surface which must be penetrated before the grass roots, where the larvae cling, are reached.

October 15: I thoroughly examined the area treated with Phinotas oil on the tenth. Two hours were spent in fishing around the tussock tufts, as well as elsewhere, and in that space of time I secured only four larvae, two dead ones and two that were very much alive. Thus it appears that dead larvae are not so easily secured as are live ones since larvae were really abundant before the application.

About ten feet distant from the area treated with Phinotas oil larvae were as numerous as previously, even though a thin coating of oil was present over the surface where it had spread from the treated part.

DESCRIPTION OF THE LARVA

Length 6–7.5 mm. (.24–30 inch) from head to end of ninth abdominal segment. Robust, resembling in life larva of *Psorophora columbiae.* White, tinged with clear transparent green which is often predominating hue. Head pale brown, much broader than long, rounded in front

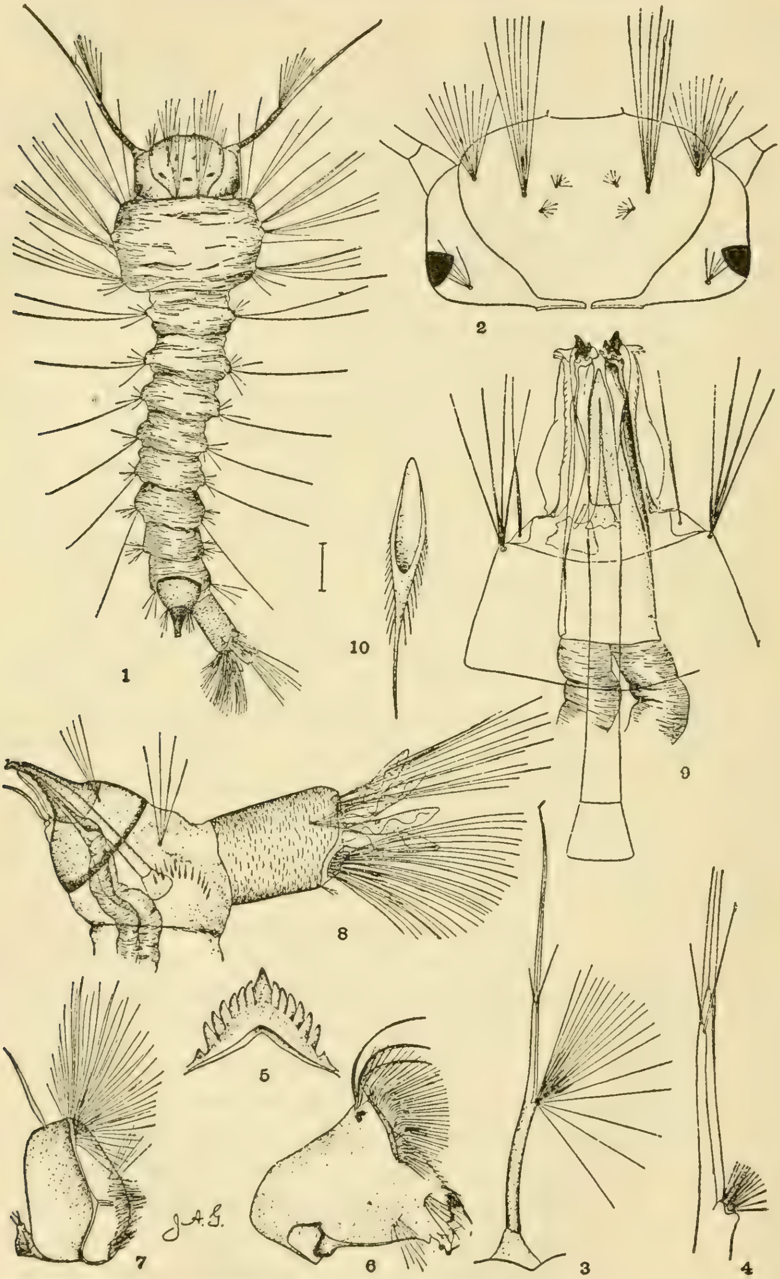


FIG. XXVII. Larva of irritating mosquito. *Mansonia perturbans* Walk. (After John B. Smith.) 1, larva in fourth stage; 2, head showing position of hair tufts; 3, antenna; 4, part of same, yet more enlarged; 5, mentum; 6, mandible; 7, maxillary palpus; 8, caudal segments of larva; 9, anal siphon; 10, a single lateral scale (all enlarged).

and flat at sides; four large and four small tufts of hair arise from vertex, two of large ones of six or seven hairs each from central portion, between which four small tufts are situated, one of ten or eleven hairs near base of each antenna. Of small tufts anterior pair are each composed of six hairs, posterior pair of seven each. Another pair of moderate sized hair tufts near base of head just below and inward of eyes; composed of five hairs each. Eyes remarkably small, black and placed far down on sides of head. Antenna very long and somewhat filamentous, infuscated at basal third and almost colorless beyond; large tuft of eighteen to twenty long hairs arises from offset at basal third, and from this point shaft continued for some little distance, apparently as thickened side of hollow tube open on one side to apex of main shaft; apex terminated by two long needle-like spines, and filamentous process has very small articulated spine at end. Mentum triangular with deeply excavated base and six large teeth on each side of apical one, besides small tooth, sometimes present near base. Mandible much like that of ordinary *Culex* type, but has three curved dorsal spines and teeth small and situated some distance back from apex. In maxillary palpus subapical spine is exceptionally long and blade-like and basal process rather small with curved apical teeth.

Thorax and abdomen normal in form, former with usual number and location of long hair tufts; but abdomen has only one tuft of two hairs on each side of first segment, following five each having single long lateral hair, while segments seven and eight have none except several short hairs which are common to all segments. Eighth segment bears lateral patches of scales, each composed of from twelve to sixteen scales arranged in irregular, partly double row. Individual scale lanceolate, with long apical spine and fringes of small spines at sides. Ninth segment somewhat variable in length, but always longer than broad and completely encircled by light brown chitinous ring. Ventral brush normal but dorsal hair tufts four instead of usual two. Anal gills slightly longer than width of ninth segment and supplied with obvious trachea. Breathing tube highly complex representing extreme modification of ordinary anal siphon. Pale brown; extreme base and apical half strongly infuscated. From dorsal aspect bottle shaped with basal half greatly dilated. From side apical half curves slightly dorsally and two long blade-like spines arise from large papillae, situated on distinct dorsal offset. Constricted portion of tube provided within with projecting flaps which appear to hold inner chitinous tube in position. Apex of each lateral set of flaps furnished with six horizontally extended hooks. Inner tube, to which trachea are attached at its base, complicated structure of several distinct pieces. One small elongate piece forms ventral wall; another much larger piece extends curvedly from one edge to other. From apex of tube thus formed extend two small tubular structures, terminated at their apices by articulated, irregular, corneous piece which, by the action of the long, somewhat chitinous piece coming from the interior of the eighth abdominal segment, is capable of being thrust forward and horizontally outward. Another separate little piece on dorsal side of the main inner tube has serrated edge plainly seen from side view of the entire siphon.

MALARIAL GROUP

[Notable members of the malarial group are *Anopheles punctipennis*, *Anopheles quadrimaculatus*, and *Anopheles walkeri*. All members of this group winter in the adult form in sheltered places. All lay their eggs on the surface of water. All show very limited geographic movement.]

Anopheles punctipennis Say
The Mottled Wing Anopheles

DISTRIBUTION AND CHARACTERIZATION

[Southern Canada and United States and southward to Central Mexico. Trapped 2,674 females in New Jersey.]

Medium sized dark brown with upper surface of thorax dark brown at sides, with several narrow lines of yellowish gray hairs appearing as one broad gray stripe in center. Beak and legs unbanded; wings densely clothed with black and yellow scales, two large black patches and two smaller yellow ones on front margin especially conspicuous. Abdomen dark brown, profusely scattered with yellowish brown hairs.

DESCRIPTION OF THE ADULT

This species varies considerably in size and is of slight build. Body measures from 4–5.5 mm. (.16–.22 inch) in length; beak is just about half length of body. Head dark brown, with yellowish white mixed with brown scales in center of occiput near angle of eyes, posterior margin of eyes with faint yellow border and with tuft of yellowish hairs between eyes projecting forward over head. Proboscis uniformly dark brown. Palpi in female dark brown, with some pale yellow hairs at extreme tip, long and slender, four-jointed, first joint swollen at base, second longest, each succeeding one shorter. Male palpi three-jointed, dark brown, paler toward apex, with long hairs on central joint and tip of basal joint, basal joint very long, the apical two short, greatly swollen. Antennae dark brown in both sexes with basal joint of female paler.

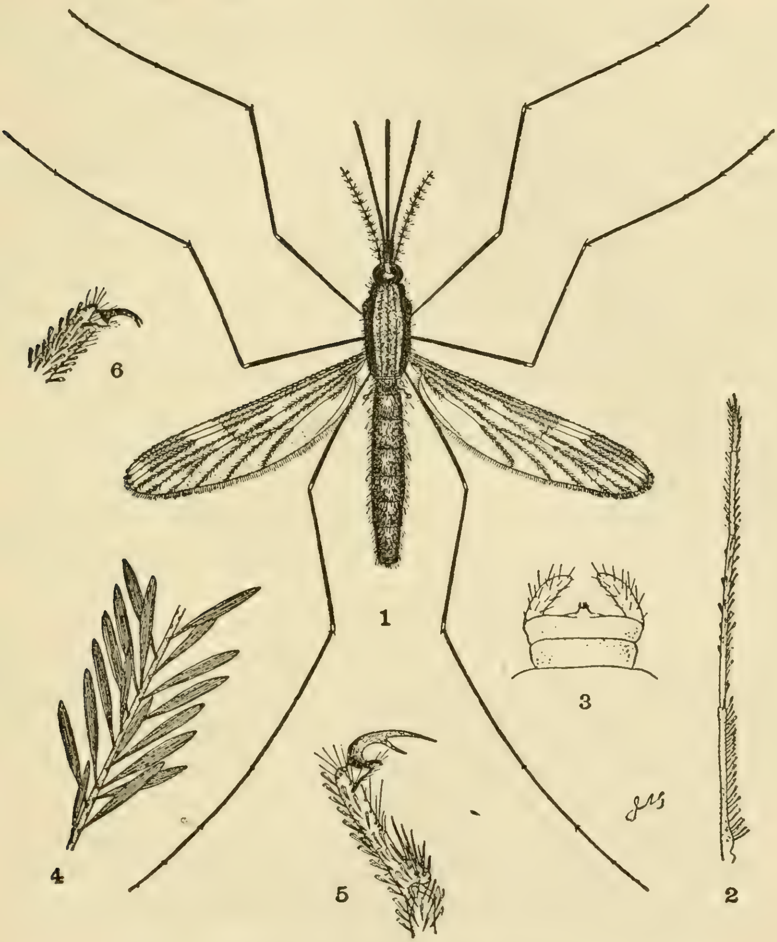


Fig. xxviii. Adult of mottled wing Anopheles. *Anopheles punctipennis* Say. (After John B. Smith.) 1, female adult; 2, her palpus; 3, genitalia; 4, part of wing vein showing scales; 5, anterior and 6, middle claws of male (all much enlarged).

Dorsum of thorax dark velvety brown at sides, with four weak median stripes of yellowish gray hairs, arranged on elevated ridges, dividing depressions brown; pleura dark brown with few scattered whitish scales. Legs very long and slender, dark brown, becoming almost black on tarsi, femora slightly paler beneath; knees and apices of tibiae have distinct yellow dot. Claws of anterior tarsal joint in male very unequal in size, large claw with median tooth and projecting extension of base which appears as tooth. Small claw very short, and simple. Claws of middle and posterior tarsal joints equal and simple, latter little smaller than the median. In female claws equal and simple on all feet. Wings hyaline, with veins covered with black and yellow scales in patches as follows: costa, basal two thirds and central part of outer third black, each end of outer third yellow; sub-costa, black; radius one, basal two-thirds and central part of outer third black, each end of outer third yellow; radius two, black at basal three-fourths, then yellow to fork, remainder black except small yellow portion of wing margin; radius three, black, sometimes with yellow portion near wing margin; radius four and five black, except for few yellow scales near wing margin; media one and two, black, divided twice by yellow before fork and again at central third after fork; media three, black with central yellow portion near base. Maculation of wing veins runs generally as given above, but more or less variable; yellow portions sometimes much larger or reduced; yellow divisions on media one and two before the fork connecting in one broad patch.

Abdomen dark brown with yellowish brown hairs evenly scattered over entire surface; beneath also dark brown, paler at base of segments.

HABITS OF THE ADULT

This species occurs throughout state and is really our common form. On the whole much more abundant south of red shale line and dominant species throughout most of South Jersey. Nothing at all peculiar or unique in its habits. Readily recognized by distinctly mottled wings; large size, largest species in state except for *Psorophora.*

[This mosquito passes winter in adult form in such sheltered places as it can find. Winter mortality usually high. Definitely shown that mosquito can transmit malaria; rarely does so in any large way.]

DESCRIPTION OF THE LARVA

Structurally larvae differ greatly from those of *Culex,* possessing very complex respiratory apparatus, adapted to surface feeding habit. Full grown larvae 6–6.5 mm. (.24–.26 inch) to end of ninth segment. Body of young larvae, exclusive of head and chitinized parts of respiratory tube, pale yellowish white, almost transparent, except broad alimentary tract, which is dark gray or black; large larvae usually gray, or brownish gray, but often clear pale green; only in latter case is alimentary tract visible. Longitudinal stripe, broken by small dorsal plates, runs down center of dorsum, and usually white in color, rarely bright pink, narrow, though widened at each of segmental sutures.

Head is rounded, as long as broad, with distinct offsets for reception of antennae; pale yellowish brown with basal half of vertex maculate with brown as shown in Fig. XXIX. There is some variation in size; smaller spots may be consolidated with larger; but it is always well defined and seemingly very constant in form. Maculation of same pattern present also in young larvae. In middle of vertex, in transverse row, six rather long, equally spaced feathered hairs; several small, similar ones situated farther back. Eyes crescent-shaped with small spot in concavity. Antennae (Fig. XXIX) two-jointed, first very short, immovably attached to head, second comparatively long, thickest near base, tapering evenly toward apex and terminated by six long hairs and two spines, latter serrated on one edge. Surface of second joint set with small spines, and four-branched hair representing tuft, situated on shaft at about one-fourth its length from base. Rotary mouth brushes very small, but dense, and composed entirely of simple hair. Mentum somewhat pentagonal, two front angles with five large blunt teeth, sides with two smaller pointed teeth, and basal angles greatly elongated. Mandible (Fig. XXIX) stout and chunky, with two large and several smaller teeth at apex, two spines below serrated on inner edge; on dorsal surface three large curved spines, one simple, others feathered on one side. Few hairs of dorsal terminal part of transverse fan also branched. Maxillary palpus (Fig. XXIX) elongate, with four stout spines and two lamellate processes at apex; at about one-third from apex issues a stout hair which divides into a number of branch hairs.

Thorax subquadrate, angles rounded, each angle with three or four long feathered hairs; two smaller simple hairs on each side between them; several similar, small hairs on dorsal surface.

Abdominal segments transversely oblong anteriorly, becoming subquadrate posteriorly; first two have each two long feathered hairs laterally, third but one; four succeeding segments have from two to four rather short simple hairs on each side; very small simple and feathered hairs at base of long hairs on all segments. On dorsal surface, near bases of segments three to seven, two small palmate hairs, and in center, at apical margin of segments one to eight, small chitinized plates and sometimes extremely small circular dots below them. Eighth segment bears respiratory apparatus; very complex organ, which projects backward over ninth segment as seen in side view. Tracheal tubes open on dorsal surface of this structure by two stigmata, and immediately in front of these is small plate which folds over stigmata when they are not in communication with the outer air. Posterior to these openings large partly chitinized squarish area, which comes in contact with air

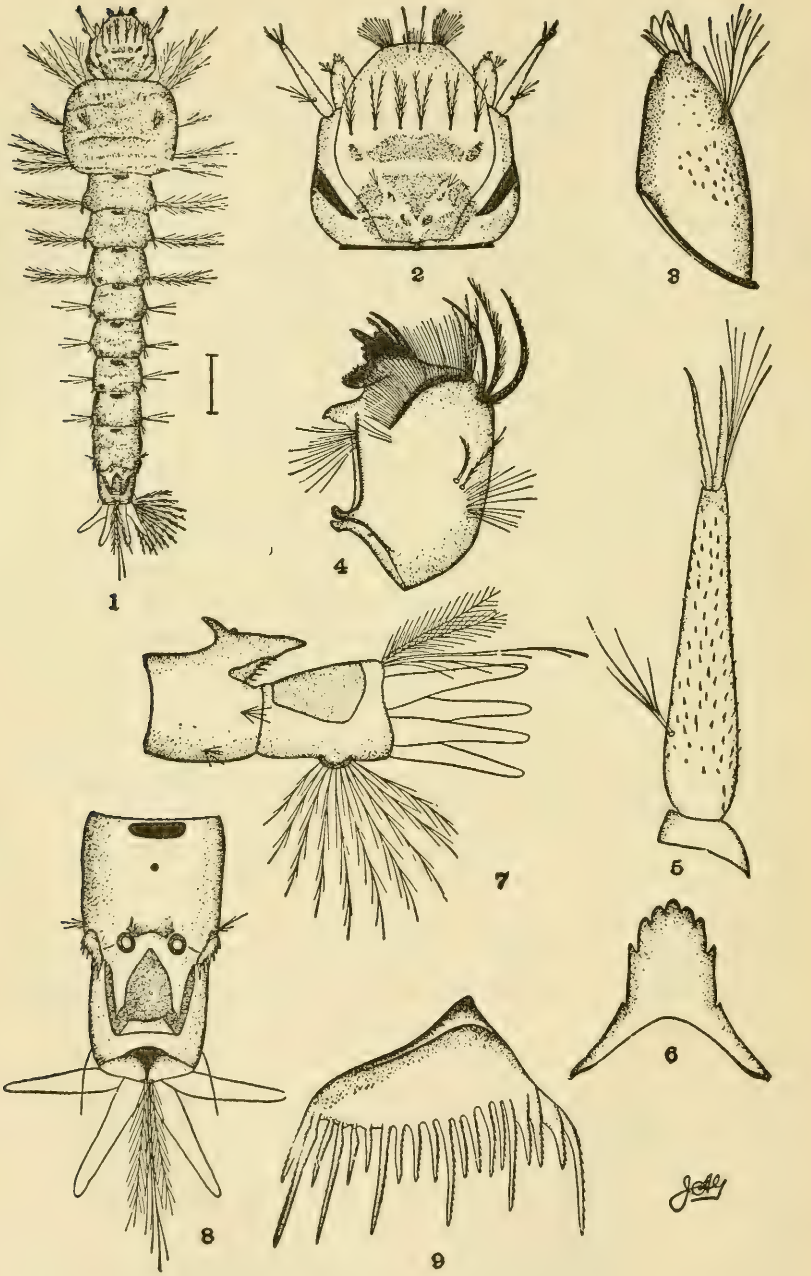


FIG. XXIX. Larva of mottled wing Anopheles. *Anopheles punctipennis* Say. (After John B. Smith.) 1, larva; 2, head above; 3, palpus; 4, mandible; 5, antennae; 6, mentum; 7, anal segments from the side; 8, anal segments from above showing the two spiracles; 9, one of the scales (all much enlarged).

when stigmata projected through surface film. At each side of this apparatus triangular plate with from six to nine long teeth on posterior margin and one to four short teeth between, usually about twenty in all.

Ninth segment longer than broad, widest at outer end; dorsum covered with chitinized saddle which extends half way down sides. Dorsal tuft composed of two very long branched hairs and two shorter feathered ones; on ventral surface semicircular process from which issue about nine long branched hairs with fan-like arrangement. Tracheal gills fingershaped, blunt at apex and slightly longer than ninth segment.

[Five pairs of float hairs on this species all about same size differing from *Anopheles crucians* in that respect. *Crucians* shows first and second pair of float hairs smaller than rest.]

HABITS OF THE EARLY STAGES

There is nothing peculiar to this species in the development from egg to adult. The larvae occur throughout the state wherever conditions favor and almost any body of water, large or small, clean or moderately foul, will serve to breed the pests. On the whole it breeds most abundantly in clean water along the edges of ponds or swamp areas or in the eddies of shallow streams.

Anopheles quadrimaculatus Wiedman
The Four-Spotted Anopheles

DISTRIBUTION AND CHARACTERIZATION

[North America east of the Rocky Mountains from Canada to Mexico. Trapped 7,893 females in New Jersey.]

Similar to *Anopheles punctipennis*, but much lighter brown in color; thoracic stripe, more yellow, does not stand out so clearly in contrast. Wing veins clothed with brown scales, some of which gather into four very distinct patches, a character which distinguishes it from all other species at a glance.

DESCRIPTION

Howard, Dyar, and Knab (14) offer the following description of female, male, larva, and egg of this species:

"*Female*. Proboscis long, straight, slender; labellae long, lanceolate, dull, luteous, with small outstanding black setae; vestiture appressed, dark brown. Palpi as long as proboscis, uniform, slender; vestiture of dark brown narrow scales, roughened at base, a few stiff setae at tip.

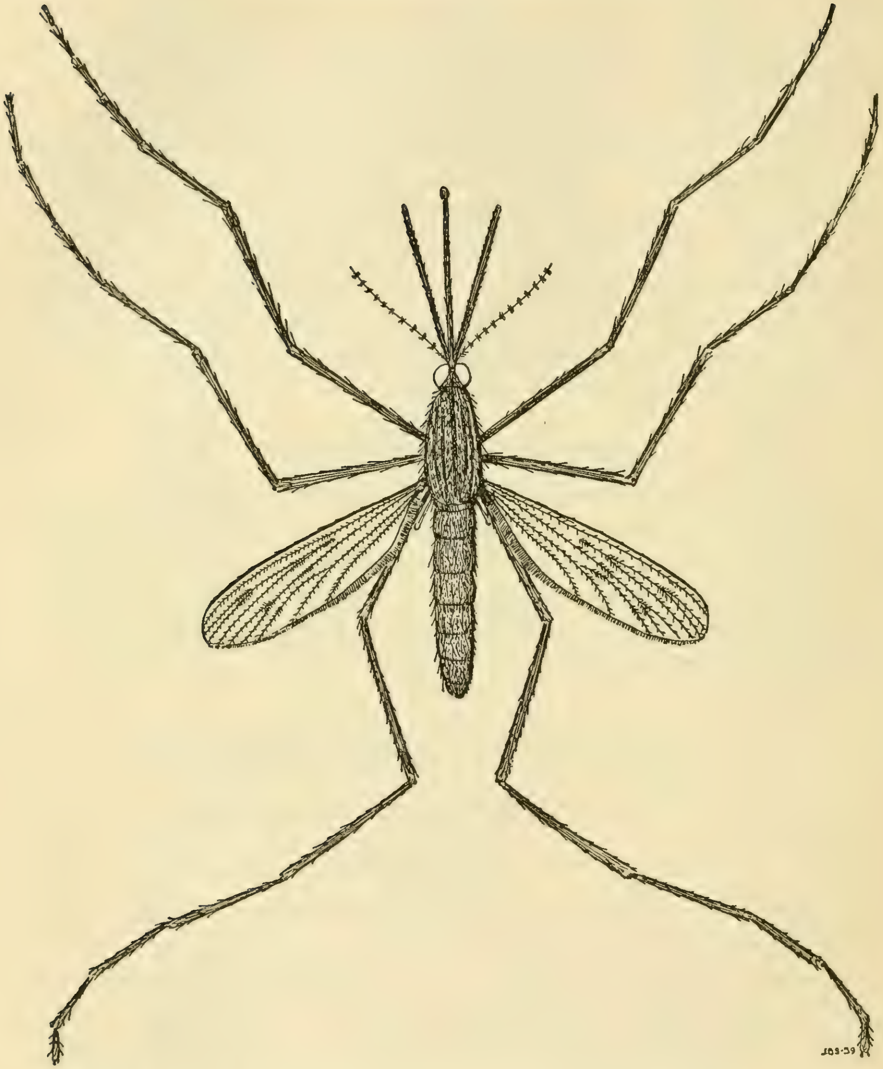


Fig. xxx. Adult of four-spotted Anopheles. *Anopheles quadrimaculatus* Say.

Antennae filiform, the joints subequal, rugose, blackish, pilose; hairs of whorls sparse, black, short; tori subspherical, with a cup-shaped apical excavation, small, blackish. Clypeus elongate, elliptical, dark brown, nude. Eyes well separated, black. Occiput with a median groove, blackish, densely clothed with erect, triangular, or notched scales, black on sides and at extreme base, whitish anteriorly, a tuft of long white hair scales projecting forward between the eyes; a row of black setae along margins of eyes.

"Prothoracic lobes lateral, small, elliptical. Mesonotum narrow, depressed, brown, three darker longitudinal stripes on the disk, grayish pruinose on posterior third, sides behind middle dark brown; vestiture of coarse pale yellowish hair scales, densest over the three dark stripes, some stiff bristles over roots of wings. Scutellum collar-like, dark brown, with a marginal row of pale brown bristles. Postnotum elliptical, prominent brown, nude. Pleurae and coxae brownish luteous, with a few short hairs.

"Abdomen subcylindrical, somewhat depressed, truncate at tip, luteous brown, the apices of the segments broadly blackish; vestiture of numerous pale bristles arising from small black punctures.

"Wings moderate, hyaline; petiole of second marginal cell shorter than it's cell, that of second posterior cell about as long as its cell; basal cross-vein distant about its own length from anterior cross-vein; scales of veins lanceolate, narrow, of different lengths on different areas, the long ones black, the short ones brown, the black scales denser and forming spots at the bases of the second marginal and second posterior cells, at the cross-veins and origin of second vein. Halteres with pale stem and black knob.

"Legs long and slender; vestiture brownish black, tips of femora and tibiae narrowly yellowish white. Claw formula, 0.0–0.0–0.0.

"Length: Body about 5 mm.; wing 5 mm.

"*Male.* Palpi as long as the proboscis, the last two joints swollen and club-shaped, with many long brown hairs with yellow silky luster; vestiture bronzy black. Antennae plumose; last two joints long and slender, rugose, pilose, black, the others short, pale, with narrow black basal rings; hairs of whorls long, dense, brownish with yellow silky luster. Coloration as in the female. Abdomen long, depressed, somewhat broadened distally, black, the margins of the segments narrowly luteous, hairs of dorsum yellowish; lateral ciliation coarse and irregular, brown. Wings narrower than in the female, stems of the fork-cells longer, vestiture more sparse. Claw formula, 2–0.0–0.0.

"Length: Body about 5.5 mm.; wing 4.5 mm.

"Genitalia: Side-pieces longer than wide, conical, a stout seta at middle, at base two spines from a common base, an inner setose lobe bearing four unequal spines in two groups, the outer pair with rounded tips. Clasp-filament as long as side-piece, slender, slightly enlarged at base and apex, with a short and stout articulated terminal spine. Unci slender, columnar, with two tufts of spines at tip, bent outward at right angles. Basal appendages large, delicate, leaf-like.

"*Larva, Stage IV.* Head rounded, longer than wide, bulging at the

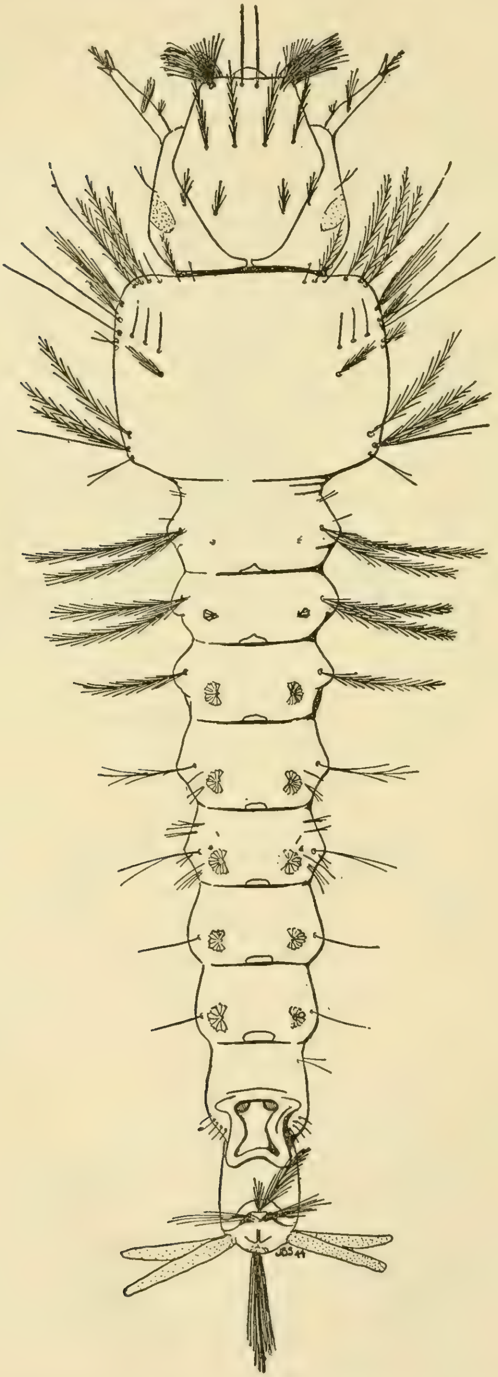


Fig. xxxi. Larva of four-spotted Anopheles. *Anopheles quadrimaculatus* Say.

sides, frontal portion before insertion of antennae conically produced; dorsal head-hairs single but numerously branched, in a line between antennae, a smaller hair at base of antennae; two long approximate setae on front margin. Antennae subcylindrical, slightly tapered, spined on one side; a tuft of four hairs at basal two-fifths; two long dentate articulated terminal processes, one short one and a small hair-tuft. Eyes large, pointed. Mental plate small, with a median tooth and four on each side, perpendicular, the first and second lateral ones subequal, the second pointed, the third distant, the fourth moderate. Mandible quadrangular, convex without; five large branched hairs on dorsal aspect in a line, two smaller ones near them; two pairs of flat appendages near tip, the distal pair feathered; an outer row of cilia; terminal dentition of eleven teeth, upper third and fourth produced; two filaments above, three within; a square finely dentate process below; a thick process at end of dentition, one at base, between these a row of setae, the central ones longest. Maxilla rounded rectangular, the palpus attached by a narrow constriction; numerous short setae and spines on inner aspect; palpus with round projecting base, a dendritic tuft within, five terminal digits and two flattened appendages. Thorax rounded quadrate, about as long as wide; hairs short, consisting of branched hairs, single hairs, and tufts, mesothorax sparsely haired. Abdomen stout, anterior segments shorter; long feathered lateral hairs on first three segments, double on first and second, single on third; posterior hairs small, smooth; a dorsal series of six pairs of fan-shaped tufts on second to seventh segments, the first pair sparse. Air-tube sessile, subquadrate, roundedly angled posteriorly. Lateral plates of eighth segment posteriorly with a series of spines irregularly long and short. Anal segment about as long as wide, with a small dorsal plate; dorsal brush a long and a short tuft on each side; a single long lateral hair below the plate; ventral brush well developed, of long branched tufts. Anal gills moderate, about as long as the segment, slightly constricted centrally, blunt pointed.

"*Egg.* Fusiform, somewhat more pointed at one end than the other, black, lower surface coarsely reticulate, dorsal surface granular; lateral floats occupying about half of the lateral margins and arcuately produced, dorsally in the middle approaching very close to the median line."

HABITS OF THE ADULT

[This species occurs throughout the state and its distribution is set forth for 1932 through 1941, as found in the summary of mosquito trap records, Table I. *Anopheles quadrimaculatus* appears to serve as the principal vector of malaria in New Jersey. No outbreaks seem to have occurred where this species is either absent, or present in small numbers. Malaria in New Jersey was very abundant in the early days but, although still sporadically present, has mostly disappeared. Winter is passed in the adult stage in such sheltered places as it can find. Winter mortality is high.]

HABITS OF THE EARLY STAGES

[In general like other species. The breeding places are similar, but this form also occurs in brackish water on the salt marshes, hence has a somewhat wider range and adds the positive danger of disease to the disadvantages of an undrained marsh.

The larva of this species may be distinguished from the larva of *Anopheles punctipennis* by the fact that the living form shows six pairs of dorsal float hairs on the abdomen while *punctipennis* shows only five pairs of float hairs.]

Anopheles walkeri Theobald

Walker's Anopheles

DISTRIBUTION AND CHARACTERIZATION

[Eastern North America. It occurs sporadically; sometimes and in some places in great numbers. It was trapped in northeastern New Jersey in the summer of 1938. A total of 10,254 specimens were trapped.

This mosquito is easily confused with *An. quadrimaculatus* and doubtless has been so identified in New Jersey collections. It is, however, readily distinguished from this species by the silvery white rings at the articulation of the last two segments and at the tip of the last segment of the palpi. *Anopheles quadrimaculatus* has uniformly dark brown palpi.]

DESCRIPTION

The following description is taken from Howard, Dyar, and Knab (14):

"*Female.* Proboscis long, straight, slender; labellae long, lanceolate, brown, with small outstanding black setae; vestiture appressed, black. Palpi slightly shorter than the proboscis, uniform, slender, clothed with narrowly elliptical scales, roughened on basal third, black, with dull silvery white rings at middle of long joint, at the articulations of last

PLATE V. TOP. Five years ago this was a garbage dump breeding house mosquitoes in New Jersey's metropolitan section. Covered with clean earth this dump has become part of a public park. BOTTOM. Larvae of the house mosquito in countless numbers were found in the tanks at this sewage disposal plant.

PLATE VI. TOP. Malarial mosquito larvae were taken from this pool, and adult malarial mosquitoes were found resting in the barn shown in the background. BOTTOM. Collecting larvae in early spring from a breeding place of the woodland-pool mosquito.

two joints and at tip of last one, outer portion of long joint and last two joints with rather coarse bristles. Antennae moderate, filiform, the joints subequal, rugose, black, with long pile, a few silvery white scales on second and third joints; hairs of whorls sparse, black, short; tori subspherical, with a cup-shaped apical excavation, small, blackish. Clypeus elongate elliptical, brown, nude. Eyes well separated, black. Occiput with a median groove, blackish, integument at margins of eyes white, vestiture of erect triangular pale scales, their stems dark, some slender recumbent whitish scales anteriorly, a tuft of long white setae projecting forward between the eyes; a row of black bristles along margins of eyes.

"Prothoracic lobes lateral, small, elliptical, with some coarse brown bristles. Mesonotum narrow, elongate, brownish gray, slightly lighter pruinose in two narrow stripes on anterior half; vestiture of short, sparse, golden brown hair-like scales, slightly denser medianly; bristles at roots of wings coarse, brown. Scutellum collar-like, luteous, with a row of rather dense, long brown bristles. Postnotum pale brownish gray, shining, nude. Pleurae brown, pruinose; coxae luteous, with a few short hairs.

"Abdomen subcylindrical, somewhat depressed, truncate at tip, brownish gray, slightly rugose; vestiture of numerous short brown bristles with golden luster.

"Wings moderate, hyaline; petiole of second marginal cell much shorter than its cell, that of second posterior cell about as long as its cell; basal cross-vein distant about its own length from anterior cross-vein; scales of veins long and narrow, nearly linear, brownish black, rather uniformly distributed, only slightly denser and darker in the region of the cross-veins and at the bases of the fork-cells. Halteres brownish.

"Legs long and slender; vestiture blackish brown, knees and apices of tibiae paler."

[The first recognized adults were taken in mosquito traps by Robert L. Vannote, superintendent of the Morris County Mosquito Extermination Commission. Since that time *An. walkeri* has been trapped at various points in northeastern New Jersey. Larvae, supposedly *An. walkeri*, have been collected from pools near where the adults were taken in large numbers, but the question of their identity has not yet been settled.]

The illustration and description of the larva of *Anopheles walkeri* has been omitted because of its similarity to all the other common New Jersey anopheles species.

King, Bradley, and McNeel in *The Mosquitoes of the Southeastern*

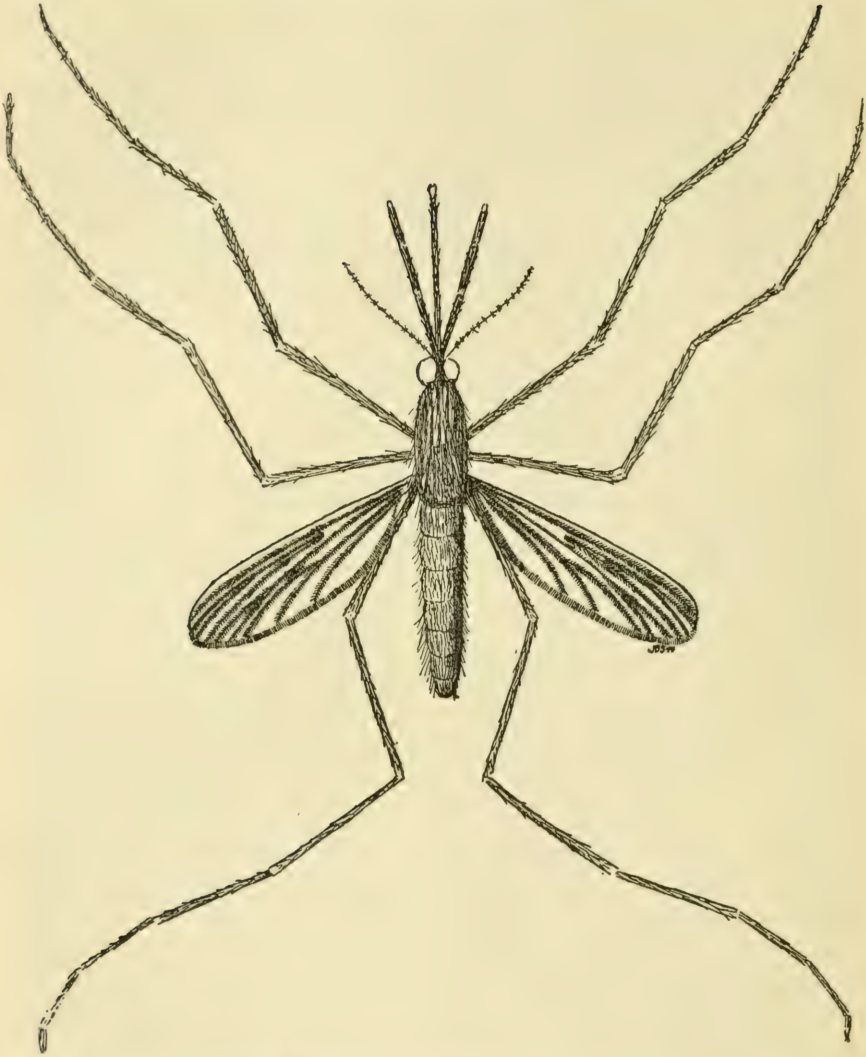


Fig. xxxii. Adult of Walker's Anopheles. *Anopheles walkeri* Theob.

States describe *An. walkeri* as resembling *An. punctipennis* very closely. They state that *An. walkeri* has the "inner clypeal hairs with sparse minute feathering toward tip; hair of prothorax with three to five strong branches from near base. (Hair on abdominal segments comparatively large, with three to seven branches; palmate hairs on segments one and two partially developed; antepalmate hairs on segments four and five usually single, sometimes double or triple.)" *An. punctipennis* differs from *An. walkeri* in having "the inner anterin clypeal hairs simple (rarely forked toward tip), hair one of prothorax short, single or weakly branched at tip; palmate hairs rudimentary on segments one and two."

WOODLAND POOL GROUP

[The notable members of the woodland swamp group are *Aëdes canadensis, Aëdes stimulans, Aëdes excrucians, Aëdes trivittatus, Aëdes triseriatus,* and *Aëdes sticticus.* All members of this group winter in egg or larval forms. All members normally lay their eggs on moist surfaces near pools or in depressions. All show only very limited geographic movement.]

Aëdes excrucians Walker
The Brown-Striped Woods Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northeastern North America. Trapped twenty-three specimens in New Jersey.]

A species closely resembling *Aëdes stimulans* but smaller, darker in color and with a brown line or stripe in center of thorax. Abdominal bands grayer than in *stimulans* and much more diffused.

DESCRIPTION OF THE ADULT

Medium sized, 5–6 mm. (.20–.24 inch) long, including beak, which is just about half length of body. Head brown; occiput covered with pale yellow scales which extend forward between eyes; palpi in female dark brown, four-jointed, terminal joint small, oval in form, pointed at apex and slightly spiny; proboscis pale brown with dark brown scales scattered over surface, entirely covering apical fourth. Male palpi similar to *canadensis* in shape, brownish, with pale band in center of basal joint and at two terminal ones; fan-like tufts dense, silky brown. Antennae brown in both sexes, basal and two succeeding joints in female testaceous.

Thorax covered with mixed pale yellow and brown scales at sides and with median stripe composed wholly of brown scales, pale scales of sides sometimes forming narrow border to this brown stripe; pleura brown, clothed with patches of dirty white scales. Femora yellowish beneath and at extreme apex on upper side, remainder covered with mixed black and white scales; tibiae and first tarsal joints blackish brown, sprinkled with whitish scales; all other tarsal joints black. Fore and middle tarsi

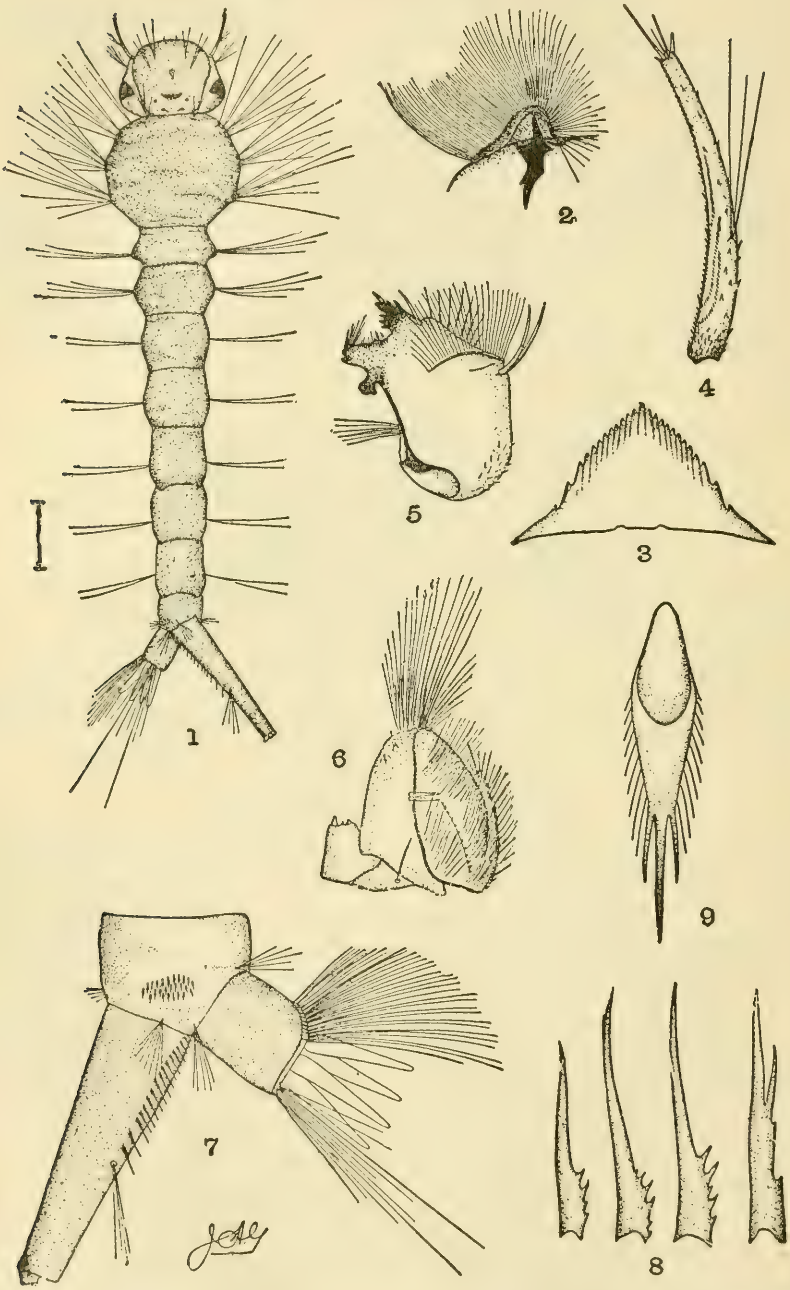


Fig. xxxiii. Larva of brown-striped woods mosquito. *Aëdes excrucians* Walk. (After John B. Smith.) 1, larva; 2, mouth brush; 3, mentum; 4, antenna; 5, mandible; 6, maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines; 9, a single scale of eighth segment (all enlarged).

narrowly ringed with white at base of joints except fifth one in anterior feet; posterior tarsi with broad basal bands of pure white. Claws of anterior tarsal joint in male very stout, unequal in size and each with large median tooth; those of middle tarsal joint unequal, the larger long and slender with long blunt tooth one-third its length from the base, the smaller with a median tooth near the base. Posterior claws equal, each with median tooth nearer base. In female claws equal and slender on all feet, with single long tooth near base of each.

Abdomen blackish brown with pale yellowish bands at base of segments; extremely narrow apical ones at base of posterior three segments, irregularly merging into brown, becoming diffused at sides until, beneath, scales are mixed together indiscriminately, white ones predominating. Bands of male very wide, mixed with brown scales and tend to cover entire posterior segments.

HABITS OF THE ADULT

Nothing is known of the habits of this species in the adult stage. We know, of course, that it is a woods mosquito, and it probably stays there. We know also that it is an early species and the probabilities are that there is only one brood.

DESCRIPTION OF THE LARVA

Measures 9–11 mm. (.36–.44 inch) in length, exclusive of the anal siphon when full grown; not robust. Body light gray or yellowish brown in color with thorax somewhat darker. Head about one and one-half times as broad as long, yellowish to light brown, though vertex often dark so as to give appearance of dark brown head. Posterior part of vertex has maculation of four spots and semicircular blotch often obscured. Four tufts of two hairs each situated on top of head in anterior part and larger tuft at base of each antenna. Antennae moderately long, somewhat sharply curved, surface sparingly set with spines, rather thickly at base; three or four regular rows of minute spines run from base toward apex on inner side. Tuft is well below middle and consists of but two or three hairs. Antennae brown, very dark toward tip, apex with three spines of different lengths, a very short spine and a small joint. Eyes large, black; rotary mouth brushes pectinated in central hairs. Mentum has slightly curved edges of eleven or twelve teeth on each side of apical one, and becomes very broad at base. Mandible normal, with group of small spines at base. Maxillary palpus set with spines and patches of hair over surface and has a chunky little joint at its base.

Thorax as long as broad, only slightly angulated at sides, lateral tufts moderately long; two very small tufts on anterior margin.

Abdominal segments from one to seven are oblong or subquadrate, with three or more hairs to lateral tuft in first and second segments, and two hairs to tuft in following segments. Eighth segment has from twenty-four to thirty scales to each of lateral patches; single scales long, with three spines at apex and very fine ones along sides. Anal siphon pale yellow, slightly darker near tip; about five times as long as its width at base and evenly tapered toward apex. Spines, from fifteen to twenty-two in each row, extend almost to middle; vary in size, and in number and length of teeth; short ones always toward base; apical two longest and separated from rest and from each other. Siphonal tufts at the end of the row have but three or four long hairs. Ninth segment slightly longer than broad with usual dorsal and ventral tufts. The anal gills are stout and moderate in length without visible trachea.

Larva differs obviously from that of *stimulans* in antennal structure, in form and arrangement of scales on eighth segment and in form and armature of anal siphon.

HABITS OF THE EARLY STAGES

Four larvae, rather well grown, were collected April 25, in the swampy woodland at Livingston Park, with *Aëdes canadensis* and *Corethra cinctipes*. They were at once recognized as distinct and separated from the others; but they did not do well; two died and on May 7 everything that remained was put in alcohol. April 27, another collection of twenty specimens was made and May 2 as many more were brought in. The larva was not easily found, occurring only in deep pools with a layer of leaves on the bottom, among which they feed and hide. Pupation began on May 4 and on May 7 there were twelve pupae; but then a fungus attacked the remaining larvae and all were put in alcohol. The first adult emerged May 8 and all were out May 12, giving a pupal period of from four to five days.

There was no later appearance of larvae, and it is probable that there is one brood only, the winter being passed in the egg stage.

[According to Howard, Dyar, and Knab (14) the larvae appear in pools in the early spring where they hatch from overwintering eggs. There is only one brood. The larvae have a slow development and are sometimes found in pools of a permanent nature. The adults infest the woodlands during the fore part of summer and rarely, if ever, leave the woods. They bite freely even after eggs have been laid.]

Aëdes canadensis Theobald
The Woodland Pool Mosquito

DISTRIBUTION AND CHARACTERIZATION

[North America east of the plains and westward in Canada to the Rocky Mountains. Trapped 1,173 females in New Jersey.]

Distinctive characters of this species white-banded tarsi, last joints of hind pair being entirely white and joints white at both base and tip; black, unbanded beak; brown, unbanded thorax; unspotted wings and medium or rather large size. This combination of characters holds equally for both sexes and separates *canadensis* from all other New Jersey mosquitoes.

DESCRIPTION OF THE ADULT

Medium sized, not very robust in appearance. Body, exclusive of beak, about 6 mm., or one-quarter inch long; beak about one-third length of body and wings expand 10 mm., or about three-eighths inch. Head brown, largely taken up by black eyes; beak black or blackish, without marks or rings; palpi in female short, blackish, four-jointed, set with rather stout and moderately long hair, terminal joint very small, yet not retracted nor shrunken. In male palpi as long as beak, black, basal joint with two white bands, second and third joint also incompletely banded at base. Toward tip palpi have dense, fan-shaped tufts of hair inwardly.

Antennae of male plumose, silky brown, not much more than half as long as palpi, terminal two joints long and slender, central and basal joints cup-shaped with circle of very long silky hair. In female antennae longer, much more slender, individual joints set with both shorter and longer stiff hair and with circle of long, moderately stout hair at base of each joint.

Thorax evenly brown without obvious lines or spiny clothing. Legs black or blackish, femora yellowish on inside, white dot at knee. Tibiae set with small spines and some longer whitish hair, white at tips. All tarsi white-ringed, base and tip of each joint being white. In anterior tarsi only one well marked ring in female, others being much reduced, in male all rings almost obsolete. Middle tarsi have all rings obvious, but much reduced toward tip. Posterior tarsi have all joints white-ringed, and last joint entirely white. In male claw-joint of anterior tarsi inward excavated and set with spurs and spines, inner claw larger, with acute tooth at base and another near middle, outer claw smaller and

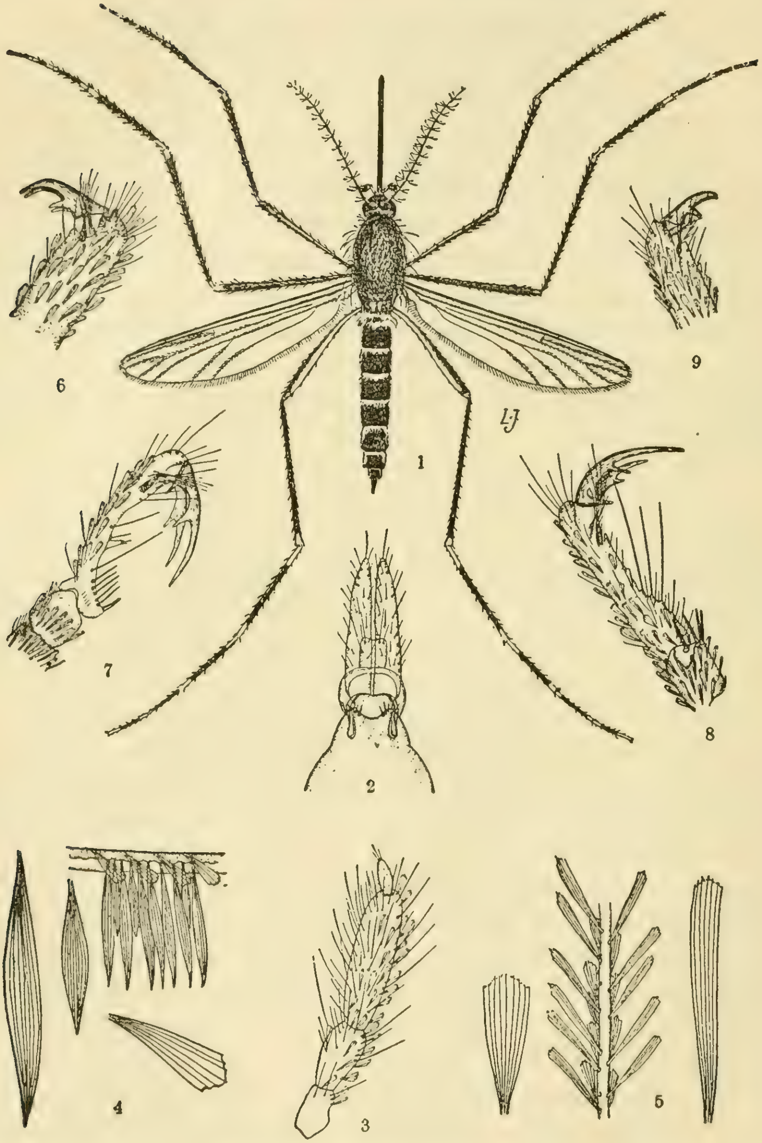


Fig. xxxiv. Adult of woodland pool mosquito. *Aëdes canadensis* Theob. (After John B. Smith.) 1, female adult; 2, ovipositor; 3, palpus; 4, margin of wing showing fringe scales; 5, part of vein showing scales; 6, anterior claws of female; 7, anterior, 8, middle and 9, posterior claws of male (all enlarged).

with only median tooth. Claw-joint of middle tarsi more normal in shape, yet a little excavated on inner side; claws similar to those of anterior tarsi, but smaller. On posterior tarsi claw-joint normal and claws small, similar, with median tooth. In female tarsal claws all alike, small, with single tooth before middle.

Abdomen black or blackish above, with narrow white bands at base, sides becoming more broadly white until, beneath, white with broad black bands. Amount of white on the upper side variable, but in fresh specimens basal bands usually distinct. In male abdominal segments better defined, white bands more clearly marked, expanding at sides; surface covered with fine, long, divergent hair.

Range of variation small; considerable difference in size, and some difference in intensity of body color. Apparent variation in distinctness of white abdominal bands usually due to age of specimen, all fresh examples showing clear contrasts.

HABITS OF THE ADULT

This is essentially a woods mosquito. It bites hard when it gets a chance and readily attacks those who venture into its domain, but is easily scared off and never follows into the open. Nor does it get into houses or even on porches, except where a house is practically in the woods. It is almost never found in cities, towns, or villages, so, though it is really one of our common species, it is not to be accounted a very troublesome one.

During the day it is not readily started, except in the darker woods; but in the early morning and at dusk it flies readily and may get for a short distance away from its normal shelters, but is in no sense a migrant. The males live only a few days; the females seem to remain for several weeks.

DESCRIPTION OF THE LARVA

Full grown wriggler measures from 7–8 mm. (.28–.32 inch), excluding anal siphon; rather stout, very active, usually dirty slate gray, except head, which is usually black. Little variation in color of mature larva, but in earlier stages lighter, and head seems darker in contrast. Up to time when two-thirds grown, usually pale band, or neck, which gives characteristic appearance and usually identifies larva. Head, one and one-half times as wide as long, varies in color from yellowish to deep blackish brown. In small larvae head black or nearly so, except after recent moult, when yellow or whitish and proportionately much larger. Sometimes this pale color persists and detracts so much from usual ap-

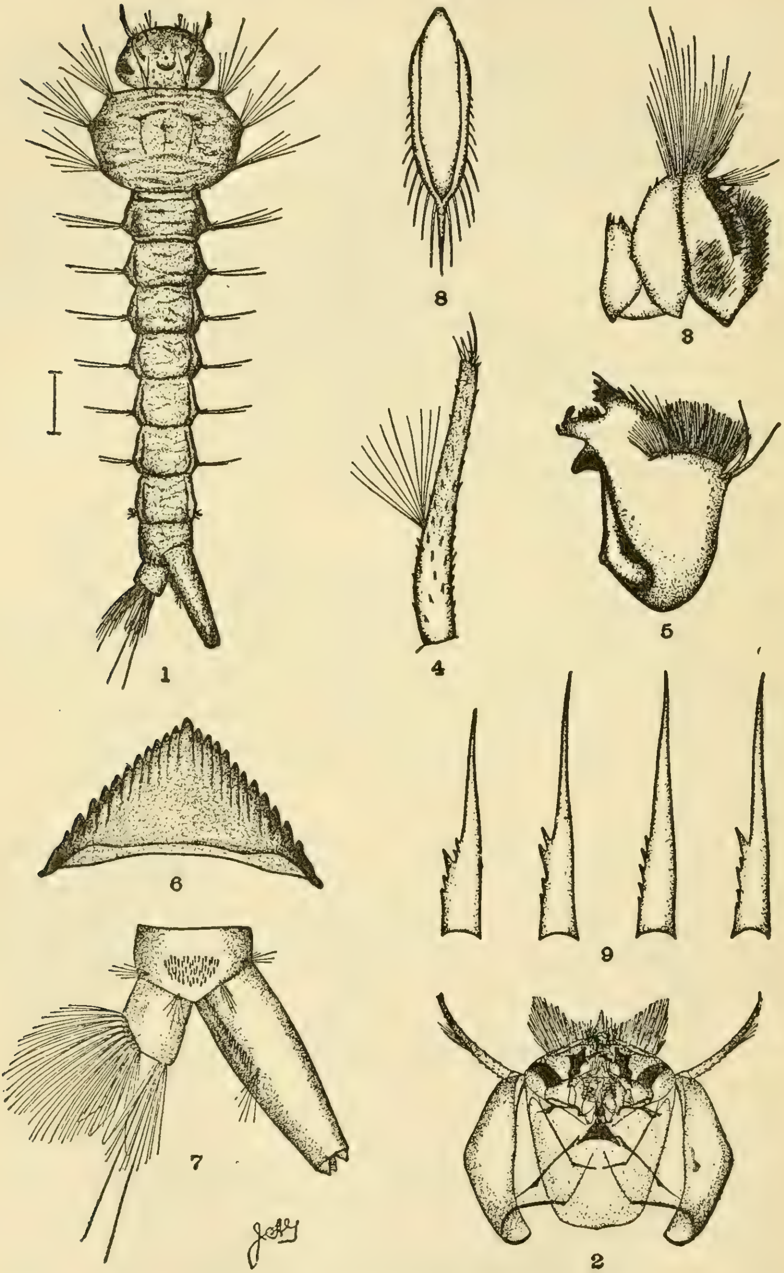


FIG. XXXV. Larva of woodland pool mosquito. *Aëdes canadensis* Theob. (After John B. Smith.) 1, larva; 2, head beneath; 3, maxillary palpus; 4, antenna; 5, mandible; 6, mentum; 7, terminal segments and siphon; 8, a single scale of eighth segment; 9, siphonal spines showing variation (all enlarged).

pearance that it gives impression of different species. Maculation on vertex shown in Fig. XXXV very constant, does not vary from definite pattern shown. Marks and dots never very prominent; and the darker the general color of head, the less obvious they appear; but usually can be discerned. Four tufts of four or five hairs each on head, two on each side of center, one pair a little ahead of other, and larger tuft at base of each antenna. Antennae short, slender, light brown, paler at base, set with sparse stout spines and more numerous very small ones. Viewed from side antennae slightly bi-sinuate, *i.e.*, makes both an in and out curve on each margin. Tuft composed of from six to ten long hairs and situated well below middle. Apex has both a long and a short spine, two bristles and little joint, all articulated to main segment. Eyes black, of good size, somewhat kidney-shaped, occupy the widest part of the head. Central hairs of rotary mouth brushes very finely comb-toothed or pectinated. Mentum very constant, triangular in form, with from twelve to fourteen teeth on each side of apex, toothed edges only slightly curved. Mandible characteristic in form and best described by reference to figure. Maxillary part bearing palpus has large tuft of moderately long hair, inner surface well clothed with hair arranged in rows and patches. Thorax angulated at sides, one and one-half times as broad as long, dorsum a little depressed and wrinkled, each of three lateral angles with tuft of long hair arising from tubercle, and two tufts of two hairs each, at anterior margin. Abdominal segments one to seven oblong or subquadrate, each with lateral hair tuft which becomes smaller and shorter posteriorly. Eighth segment has lateral patches of from twenty-five to fifty elongated fringed scales, forty being average. These scales approximately constant in all stages, but fewer and differently arranged in smaller larvae. Anal siphon at least three times as long as broad, has two series of toothed spines, each series ranging from sixteen to twenty-four, eighteen being about average. In mature larva color like that of body, but in early stages tip is black. Ninth segment subquadrate in outline, dorsal part of apical margin with two tufts in each, of which one hair much longer than others; ventral part of margin with barred area from which arise ten to twelve tufts of from five to seven hairs each. Anal gills moderately long and not supplied with obvious trachea in later stages.

Young larva in captivity, when undisturbed, has habit of using anal siphon as a pivot around which it swings with head bent upward so as to feed on material just below or at the surface. In all stages larva are more nearly parallel to surface than are most of the other *Aëdes* species.

HABITS OF THE EARLY STAGES

This is the earliest and latest of the species that winter in the egg stage: earliest as to both adult and larva, and latest as to larva only. The extreme records for either direction show larvae hatched in November and again in the February following. That the February larvae did not hibernate as such is abundantly proved by the almost daily collections made during February, 1903, by the fact that larvae developed in water with a portion of the mud bottom from woodland pools and, finally, by the fact that I found the eggs in some samples of mud from the bottom of breeding pools sent in to me for examination at my request.

It was positively proved that during the early days of February, in water just above the freezing temperature (36°F.), the larvae of *canadensis* may and do hatch from the egg under entirely natural conditions. Hatching may be hastened by disturbing the material in which the eggs are laid, and this probably accounts for the larvae first found in the jars.

February, 1903, was a cold month and the breeding pools in which the larvae were found became iced over several times, so as to bar absolutely all access to the surface; nevertheless, there was no apparent decrease in the number of specimens, but, on the contrary, a continuous increase. Artificial tests were made February 18 and 19, when the bottles with baby larvae were allowed to freeze almost solid. Nevertheless they survived the test and specimens could be watched partly imbedded in ice, wriggling to free themselves until the surrounding temperature rose sufficiently to release the ice grip. In nature the larvae usually manage to escape actual freezing by getting into the bottom mud, and that was illustrated by an examination made March 2, after a night when the thermometer registered 23°. The pool was completely ice covered, a hole was chopped near the edge with an ax, and through this hole larvae were dipped up in fair numbers with the bottom material. No larvae were imbedded in the ice.

Development at this season is slow and the new hatchings during early March rapidly overhauled those that appeared earlier, so that by the middle of that month the great bulk of the brood was about half grown or a little larger. The pupal period ranges from two to seven days, according to temperature.

The earliest record for adults taken outdoors is April 14. It is not until the early days of May, however, that both sexes are at all abundant, and at that time not all of the hibernated eggs are yet hatched.

There is a false appearance of a second brood coming immediately after the first adults are on the wing; but it seems fairly certain that all the *canadensis* that are found until the middle of June are from hibernating eggs. After that time the species decreases in number, though it has been taken in all stages throughout the summer. What seems to be the second brood begins to hatch during the early days of June, and thereafter I have not been able to identify any definite period when young were present in large numbers.

[This is the first real pest mosquito to appear in important numbers in the spring. It may be found from March or April through September in all parts of the state.]

The egg is black, spindle-shaped, smooth, rather thicker than that of *sollicitans*. When the top has been lifted off to admit the egress of the larva, it looks like a stubby, half smoked cigar. This egg may be laid either on the water, through which it sinks to the bottom at the edge of a pool, or on the moist ground of depressed spots.

Breeding places are any sort of woodland pools or even larger water bodies. Larvae are found in the water covering cranberry bogs during the winter, sometimes in very large numbers. These bogs are covered with water late in fall and are kept covered until the middle of May thereafter, just long enough to mature *canadensis*. From that time until late October the bogs are dry, and when they are flooded *canadensis* adults have disappeared. The eggs must, therefore, have been laid on the bogs when they were dry, to account for the swarms of larvae found in early May. It should be noted that these bogs were closely surrounded by woodland.

I have never found the larva in open swamps or in pools far from the edge of a wood, but it was present once in a pool with *cantator* at the edge of Shrewsbury Meadow.

Our records show collections made in most of the counties of the state, and there is probably not a bit of moist woodland anywhere in it in which *A. canadensis* may not be found in early spring.

Though the larvae may be found in all sorts of pools, they are commonly of clean water. Woodland springs nearly always have some of them, and the pools in which they are most plentiful are those formed by melted snows and early spring rains over a bed of dead leaves in a depression or choked stream bed near the edge of the woodland, or in a small clearing. I have never found them in really foul water.

As nearly as can be made out from field observations, all *canadensis* eggs that hibernate hatch between February 1 and May 10, at the latter of which period adults of the earlier hatching are already out in full force and ready to oviposit. Of the eggs laid during May a fair percentage hatch early in June and give a fair second brood of adults. When these adults oviposit, an equal percentage of their eggs also develops, and this continues through the season, the bulk of each batch of eggs lying over to the next year. This keeps up an ever decreasing supply as the season advances, and yet provides liberally for the enormous spring crop in spite of the dangers attendant upon so long a quiescent period under varying climatic conditions. This accounts for the November larvae as probable progeny of adults which matured in late September or early October. It is assumed here that the larvae that hatch so late in the season do not reach maturity.

Aëdes sticticus Meigen

The Brown-Striped Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from New Hampshire southward to Texas. Trapped no specimens in New Jersey.]

A dark brown species with legs and beak unbanded, thorax yellowish with a broad median brown stripe and a smaller mark of same color on each side of posterior third. Abdomen brownish black with narrow white basal bands, which become wide at sides.

DESCRIPTION OF THE ADULT

Medium sized, about 5 mm. (.20 inch) long, exclusive of beak, which is over 2 mm., or nearly half length of body. Occiput of head dark brown, almost wholly covered with pale yellow scales, some of which collect into distinct border to eyes; on each side a small patch of dark brown scales. Palpi of female dark brown, of normal *Culex* form; but terminal joint almost obsolete; in male of same shape as in *Aëdes canadensis*, dark brown, almost black. Antennae dark brown in both sexes, with two basal joints in female pale testaceous.

Thorax covered with yellowish scales and has usually well defined broad medium stripe of brown scales, which begin almost at anterior margin and is slightly constricted centrally; also two other patches of brown scales about one-third length of thorax, at base of this stripe, on each side and separated by narrow line of yellow scales. Pleura very dark brown, with patches of pure white scales. Legs dark brown, almost black, with under sides of tibiae pale yellow and of femora creamy white, with dot of same color at apex. Claws of male anterior and

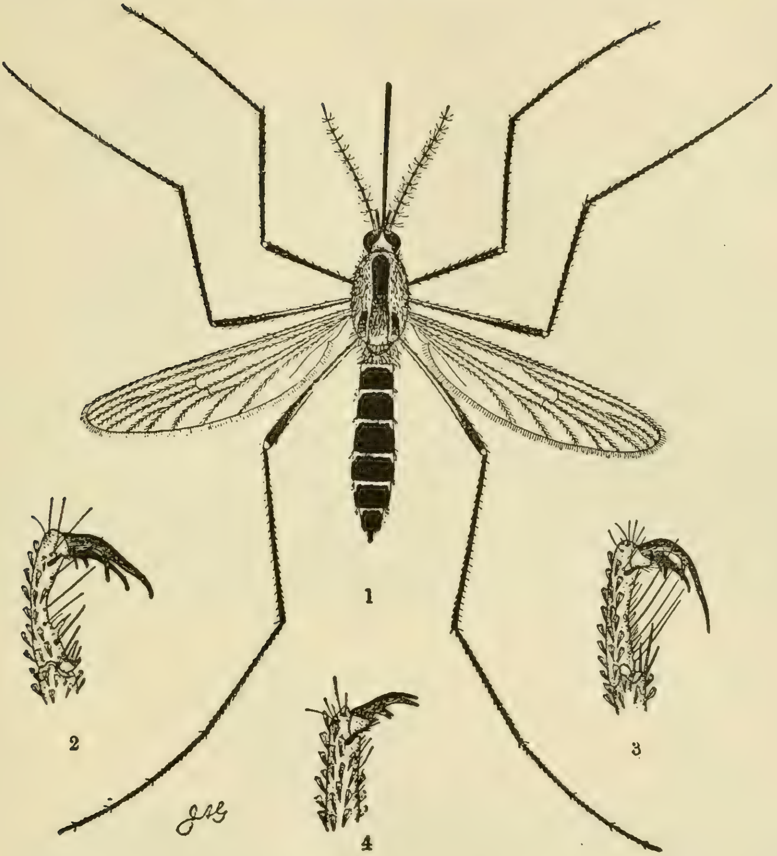


Fig. xxxvi. Adult of brown-striped mosquito. *Aëdes sticticus* Meig. (After John B. Smith.) 1, female adult; 2, anterior, 3, middle and 4, posterior claws of male (all enlarged).

middle tarsal joints unequal in size, larger with blunt median tooth and very acute basal one, smaller with single tooth near base. Posterior claws and all those of female equal in size, each with median tooth nearer base.

Abdomen brownish black, with narrow white basal bands which widen at sides, until wholly whitish beneath. Bands usually clearly defined, and though narrow rarely obsolete.

HABITS OF THE ADULT

This species is rather rare and has not been taken south of Trenton. It occurs among the early species that develop in woodland pools, two examples being bred, May 12, from pupae taken in the Great Piece meadow. Additional specimens were taken July 18 at Trenton, July 21 at Lake Hopatcong, July 30 at Chester, September 10 and 16 at Chester.

In its general habits it does not differ from the other woodland mosquitoes, and while it bites, it is not vicious and causes no unusual pain or swelling. Of its method of passing the winter we know nothing definite; but it is likely that it is in the egg stage.

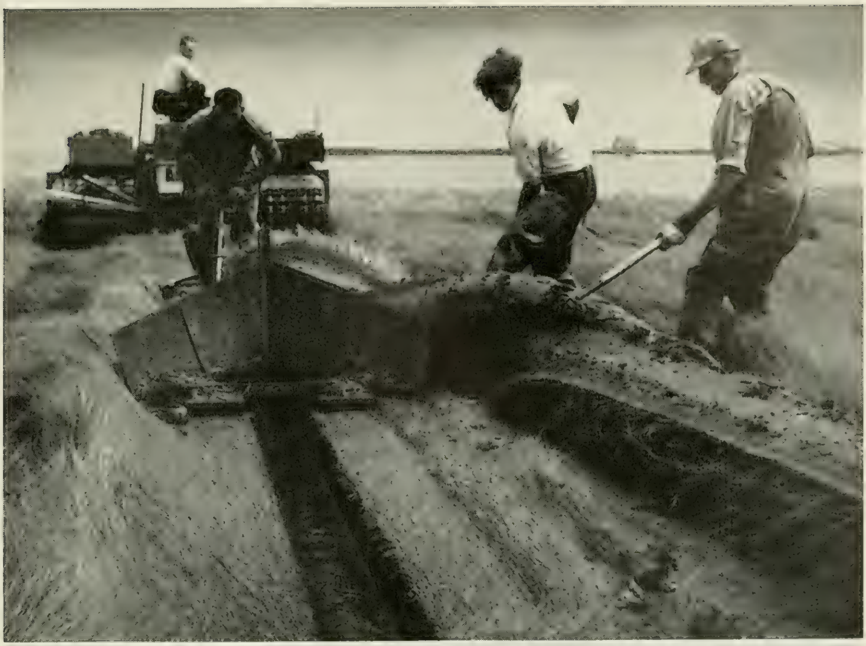
DESCRIPTION OF THE LARVA

Full grown measures 5.5–6mm. (.22–.24 inch) excluding anal siphon; pale gray to dark gray in color. Head one and one-half times as broad as long, yellowish, with large brown blotch on the anterior part of vertex, similar to *Aëdes vexans.* Four hair tufts in center of vertex, of four or five hairs each, and larger one at base of each antenna. Antennae rather short, slightly curved, pale yellow, faintly infuscated apically; thickest short distance from base and with surface sparsely set with stout spines and numerous small ones arranged in longitudinal rows. Tuft, situated well below middle, consists of eight or ten hairs which do not reach the apex; apex with one long spine, several smaller ones and a small joint. Rotary mouth brushes dense, with hairs of central part pectinated. Mentum triangular with fifteen to seventeen small teeth on each side of apex. Mandible and maxillary palpus normal, latter with moderate apical tuft and stout basal joint.

Thorax very much broader than long, with angulated sides, each angle set with acute infuscated tubercles from which issue moderate sized hair tufts. Two very small tufts near anterior margin. Abdominal segments subequal, each bearing lateral hair tufts of from two to five hairs each, larger number on anterior segments. Lateral patches of scales on eighth segment large, having from twenty-five to thirty in each patch. Individual scale elongated, with rather small apical spine and smaller ones fringing sides. Anal siphon two and one-half times, or slightly over, as long as broad, yellowish brown, thickest near base and tapering a little apically. From sixteen to twenty spines in each row, single spine with one or two teeth near base. Ninth segment almost square, nearly ringed by chitinized saddle; with double dorsal tuft and ventral brush normal and moderate in size, latter with several small tufts below barred area. Tracheal gills slender, about two and one-half times length of ninth segment, taper to a point.

HABITS OF THE EARLY STAGES

A mixture of full grown larvae and pupae was taken from a woodland pool in the Great Piece meadows May 10, 1904. All the larve were



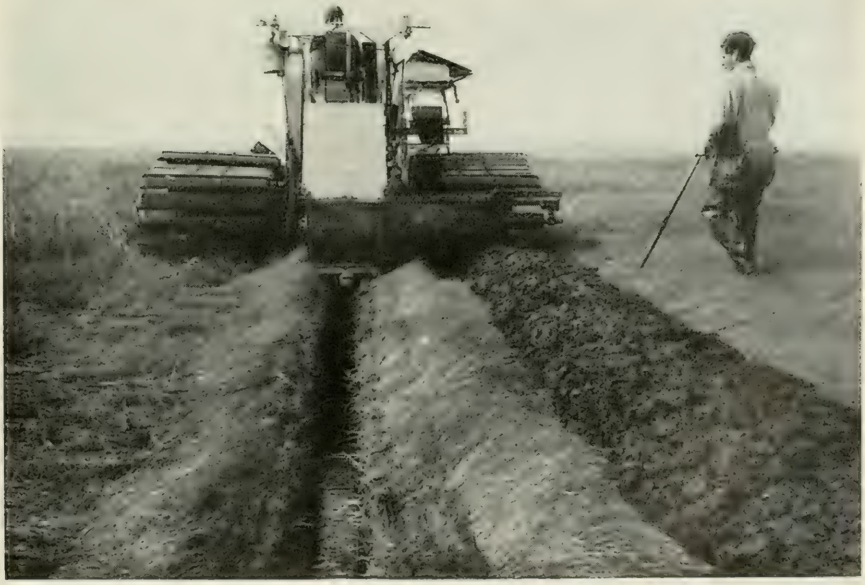


PLATE VII. TOP. The Reiley plow cuts salt-marsh ditches ten inches wide with vertical banks, depth being variable to a maximum of thirty inches. The ditch shown here is eighteen inches deep. The cut sod is deposited as a continuous ribbon. BOTTOM. This special machine developed by the New Jersey Agricultural Experiment Station can cut new ditches or recut those in need of maintenance. A continuous chain of excavating buckets, operating at high speed, grinds up the sod as the ditch is dug.

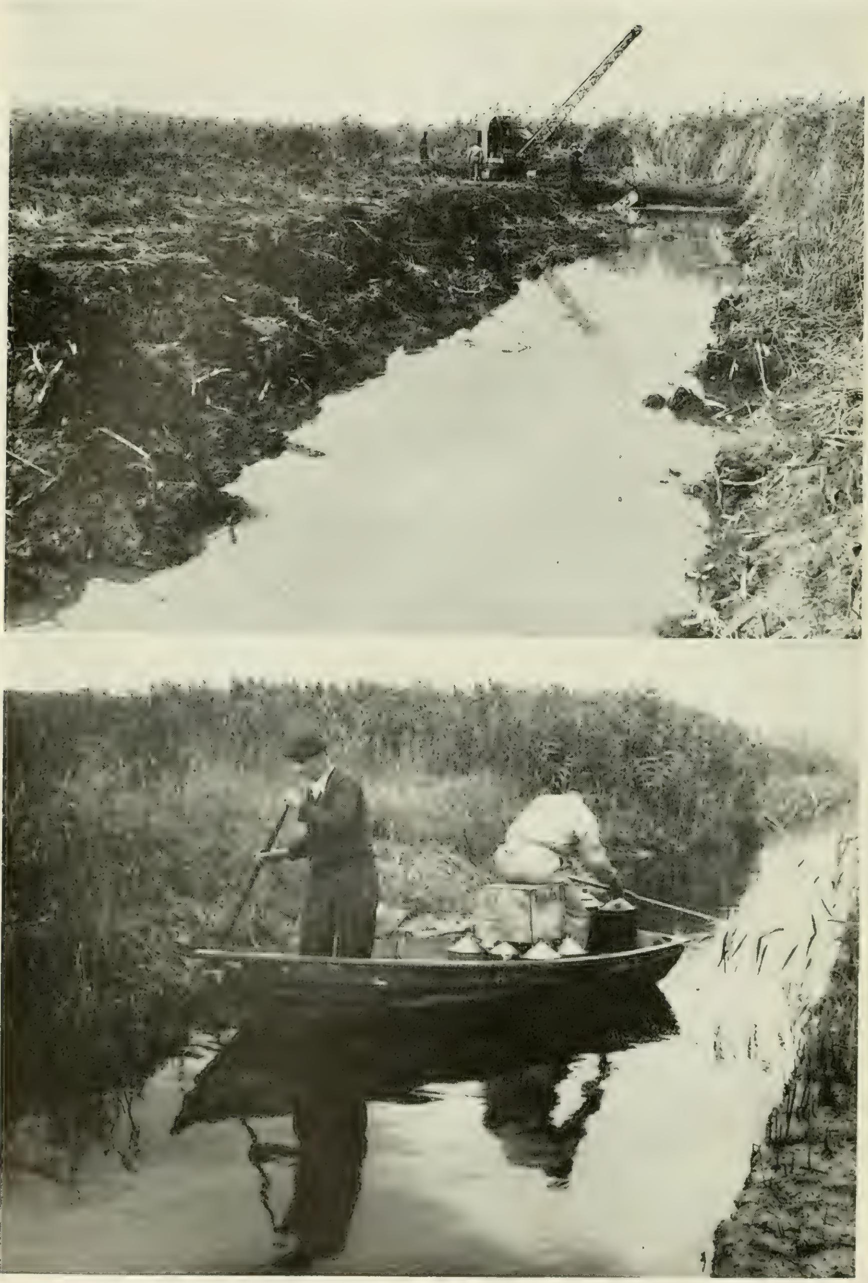


PLATE VIII. Mosquito control on salt marshes. TOP. Constructing main outlet ditch on enclosed salt marsh with caterpillar crane equipped with three-eighths cubic yard dragline bucket. Similar machines are used for upland drainage and for constructing dikes and tide gates on salt marshes. BOTTOM. Spraying with mosquito oil a main drainage ditch on a diked salt marsh so heavily sewage-polluted that fish cannot live in it.

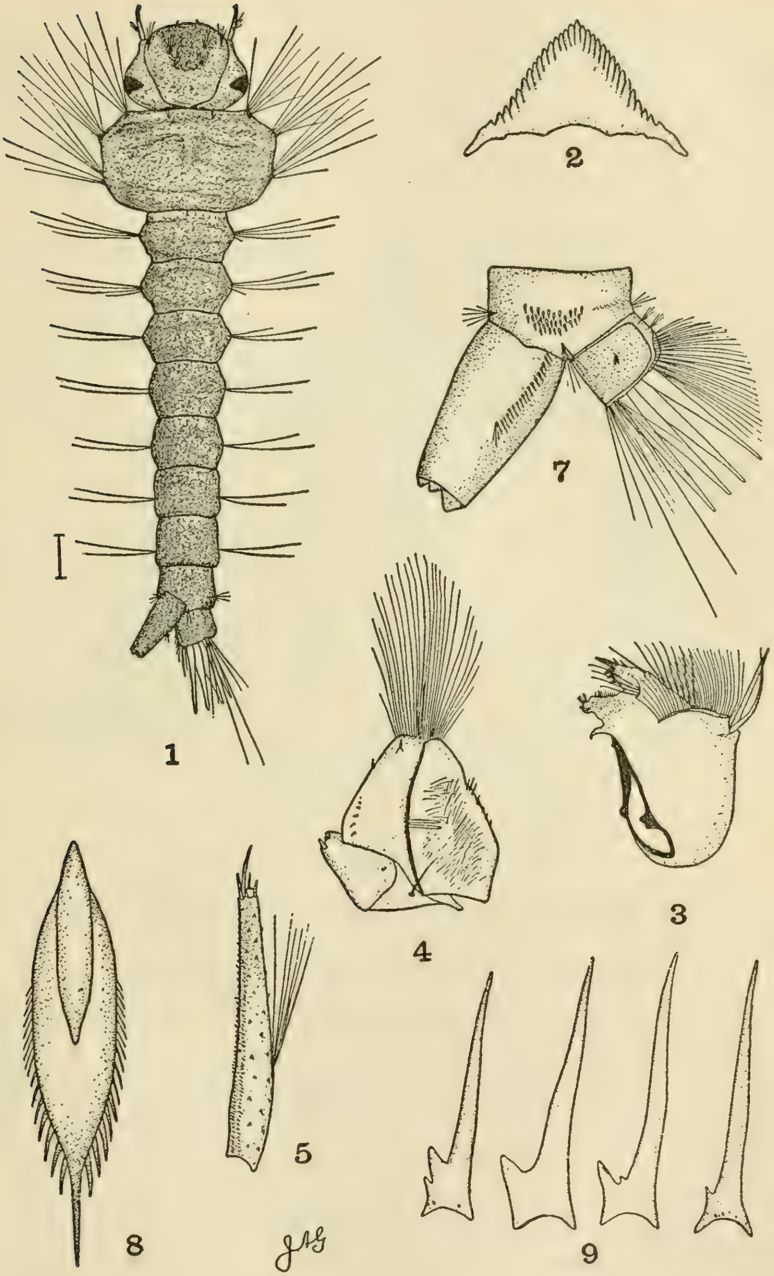


FIG. XXXVII. Larva of brown-striped mosquito. *Aëdes sticticus* Meig. (After John B. Smith.) 1, larva; 2, mentum; 3, mandible; 4, maxillary palpus; 5, antenna; 7, terminal segments and siphon; 8, a scale from eighth segment; 9, siphonal spines showing variation (all much enlarged).

put in alcohol and the pupae in breeding jars to develop. During the next three days specimens of *A. canadensis*, *A. vexans*, and *A. sticticus* appeared in the jar, and no others. Examination of the larvae showed those of *A. canadensis*, *A. vexans*, and *A. cinereus* which were known to us, and one other which we had not previously recognized and which was assumed to be the early stage of *sticticus*, as that was the only one we had not bred.

[Britton and Viereck (3) speaking of this species in Connecticut say, "Has formerly been regarded as a comparatively rare woodland species. At Hartford we found it breeding by the millions in wooded pools at South Meadows, from which it spread into the adjoining part of the city, becoming a most troublesome mosquito." This species sometimes forms a considerable part of an Upper Passaic Valley brood but does not migrate like *vexans*. Howard, Dyar, and Knab (14) believe that this species winters in the egg stage, that a part fail to hatch in the spring but do so later when the pools are again filled by rains. Thibault (28) from observations on this species in Arkansas has the following to say about it. "An early mosquito, sometimes abundant in suitable places. In thickets and grassy places and about dwellings. Does not enter houses. Breeds in transient grassy pools in fields and thickets. An eager biter. Taken in March, April, and May, and after rains throughout the summer, though only sparingly after May. Males appear first and are at times more plentiful than females."]

Aëdes stimulans Walker

The Brown Woods Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northeastern North America and the Yukon. In New Jersey 4,147 specimens have been trapped.]

It is a large brown mosquito which resembles *Aëdes cantator*, but the bands of the legs and abdomen are broader and whiter. The beak is unbanded and the wings unspotted.

DESCRIPTION OF THE ADULT

One of larger species of *Aëdes* occurring in New Jersey, at first glance looks like oversized *Aëdes cantator*. Body, exclusive of beak, 7–8 mm. (.28–.32 inch) long, beak about one-third length of body; wings expand 12 mm., or about half an inch. Head dark brown, with scattered creamy yellow scales and distinct creamy border to eyes.

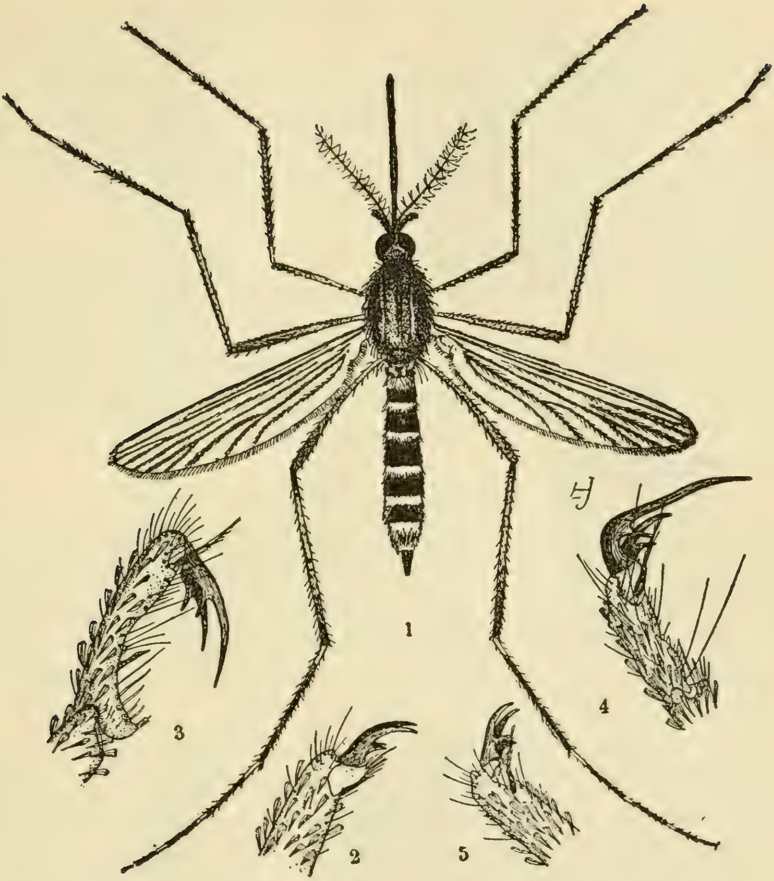


FIG. XXXVIII. Adult of brown woods mosquito. *Aëdes stimulans* Walk. (After John B. Smith.) 1, female adult; 2, anterior claws; 3, anterior, 4, middle and 5, posterior claws of male (all enlarged).

Palpi in female brown; four-jointed, apical one small, oval, pointed at apex and distinctly spiny or hairy. In male palpi wholly brown, basal joint twice as long as two apical ones taken together. Antennae of male plumose, paler than palpi, with shape and number of segments as usual. Female antennae normal.

Thorax dark brown, covered with short, upright scales, the yellow ones scattered over the surface, often collected into stripes. Legs with the femora pale brown darker at the apex, and yellowish beneath; tibiae with mixed yellow and brown scales, dark brown at apex; tarsi dark brown, almost black; broadly white-banded at base of joints in posterior legs. In middle tarsi bands are narrower and almost lost in anterior tarsi.

In male claw-joint of anterior tarsi excavated inwardly, with one long claw and a shorter one, each with median tooth, nearer base. Middle claw-joint short, not excavated, with a very long and a short claw, each with single tooth near base. Claws of posterior tarsi small, of equal length and each with a single claw. Claws of female alike on all feet, somewhat longer than those on male posterior feet; one tooth on each.

Abdomen blackish brown, broadly banded at base of segments with creamy white, which sometimes encroaches a trifle on apex of anterior segment. Bands become broader toward sides, more so posteriorly, until they connect at sides, and apical segments often wholly white. Bands very broad in male so abdomen appears white, banded with black. Under side of both sexes is dirty white.

HABITS OF THE ADULT

Little known are the habits of this species in the adult stage. It is as early on the wing as *canadensis*, occurs in the same places, bites just as hard, its life is shorter, and it seems not to range far from the place of its birth. Pain from bite is slight as compared with that of *cantator*, which it resembles so closely that the two have been supposed to be the same species. There seems to be only one brood.

[In northeastern United States and Canada, however, it is one of the most abundant and annoying woodland species. It breeds in woodland pools, flood pools of rivers and in swamps and marshes. It winters in the egg stage. Eggs hatch with the melting of ice and snow in woodland pools and adults appear in late April, May, or June. Adults are long lived, lasting until late July and August. It has a flight range of perhaps two miles.]

DESCRIPTION OF THE LARVA

Larva when full grown from 9–10 mm. (.36–.40 inch) long, excluding anal siphon, of rather stout build and usually dirty slate gray except head, which is yellowish brown. Head one and one-half times as broad as long and immaculate except for faint cloud usually present on vertex. From center of head arise two small hair tufts of two hairs each and a single, short hair in advance of each; another tuft of five or six hairs is at base of each antenna. Antennae yellowish at base, becoming dark brown toward tip; rather short, with slight curve, swollen for one-fourth its length from base, then evenly tapered to apex; apex with four spines, a long and a short slender one, two short stout ones, and a little short articulated joint. Tuft situated on shaft slightly be-

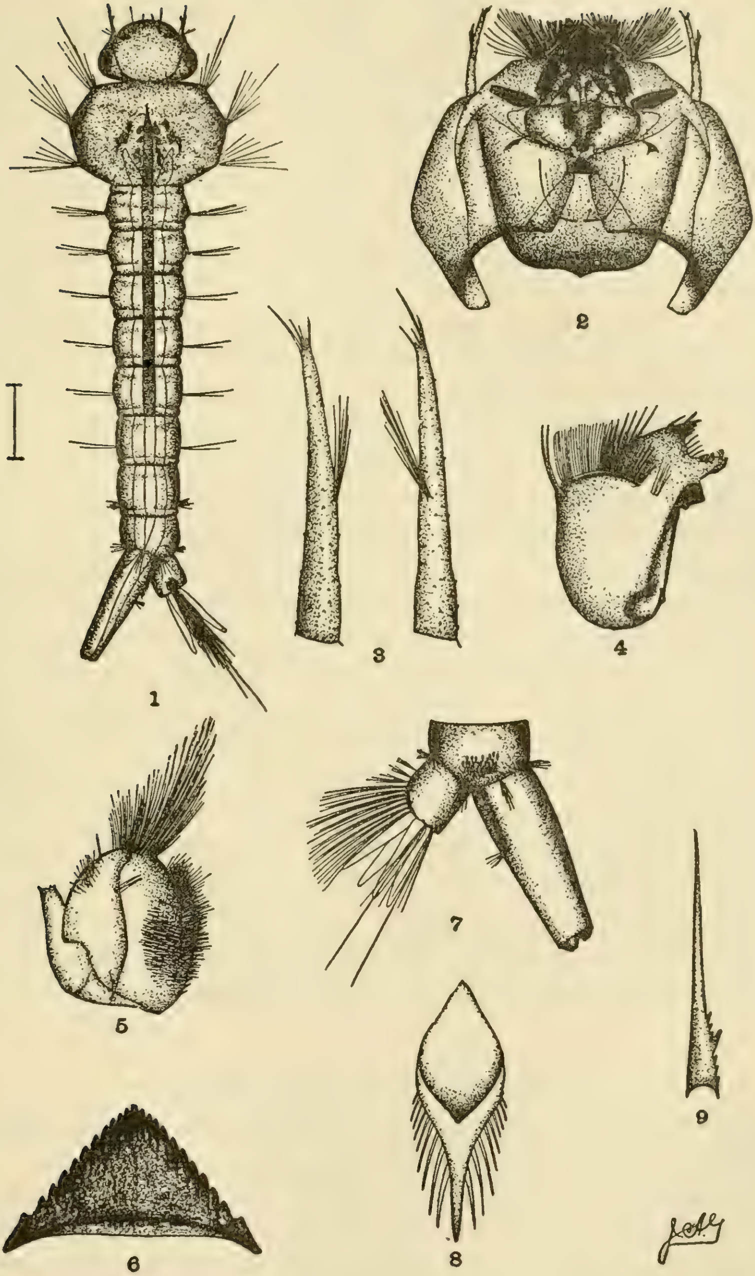


Fig. xxxix. Larva of brown woods mosquito. *Aëdes stimulans* Walk. After John B. Smith.) 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal joints and siphon; 8, a single scale from eighth segment; 9, siphonal spine (all enlarged).

low middle consists of six or eight hairs which do not reach tip. Surface sparsely set with moderate spines and numerous small ones arranged in rows. Eyes rather small, sometimes with small posterior portion separated from rest. Hairs of rotary mouth brushes numerous and heavily pectinated, especially centrally. Mentum has from nine to thirteen teeth on each side of apex, is triangular, with toothed edges only slightly curved. Mandible normal and maxillary palpus oval with moderate-sized tuft of long hair at apex, hair patches on its surface as usual and basal joint large with small spines at apex.

Thorax angulated, one and one-half times as broad as long, lateral angles with tufts of long hairs arising from tubercles and anterior margin with two very small tufts of two or three hairs each.

Abdominal segments from one to seven subquadrate, with four or five lateral hairs on first and second segments, two hairs each on segments three to six inclusive, and seventh and eighth segments with short tufts only. Lateral combs of eighth segment have from twenty-six to fifty scales, each arranged in a patch without regularity. Lateral spines fringing individual scale long. Anal siphon about three times as long as broad with double row of toothed spines, sixteen to twenty-two in each, eighteen being about average. Teeth small, generally with large one in middle and confined to basal third of spine. Ninth segment only slightly longer than broad, with barred area of ten or twelve tufts of hair on ventral part and two dorsal tufts with one long hair each. Anal gills moderately long, without obvious trachea.

[According to Howard, Dyar, and Knab (14) the black eggs are fusiform, flattened on one side, the micropylar end more rounded than the other. They are laid on the sides of the cavity just above the water line, singly, or in groups of two and five. They stand in an upright position and are firmly attached. The insect passes the winter in this stage.]

DESCRIPTION OF THE LARVA

Larva long and slender, averaging 8 mm. (.32 inch long), specimens sometimes 10 mm. long. Brownish or grayish with head and siphon darker or blackish; young and half grown larvae grayish white. Head is broader than long, yellowish to dark brown, with scarcely any darker shading. Four small hair tufts of five or six hairs each on anterior part of vertex, two long setae slightly to rear of them; another small tuft at base of each antenna. Antennae long, almost straight, dark brown, blackish toward base and without spines or hairs over surface. Single long seta arises from scarcely perceptible offset at about middle; apex one long spine, two shorter ones and little articulated peg. Eyes black, comparatively small, divided into two parts; large crescent-shaped piece and very small one in concavity; sometimes encircled by broad white ring. Rotary mouth brushes yellow, pectinated at tips of more central hairs. Mentum triangular with ten or eleven teeth on each side of apex, which become larger toward base; considerable variation, chiefly in curve of sides, as shown in Fig. XL. Mandible normal with small spines scattered near base. Maxillary palpus short and chunky, with small apical tuft and large basal joint.

HABITS OF THE EARLY STAGES

Larvae nearly full grown were collected on the outskirts of Newark March 28 and April 2. The first pupa appeared April 3, the first adult on April 6, and others continued to appear until April 12. Full grown larvae and pupae were collected at Morristown, May 1, and adults began to issue from these May 3. In both collections *canadensis* predominated and so far as our information goes the habits of the early stages are the same in both. Collections with larvae of that species were made also at Arlington, Cranford, Elizabeth, and Preakness Mountain, all in April or very early May, and it is probable that throughout the more northern part of the state *stimulans* and *canadensis* occur together in early spring. It does not occur anywhere in the pine belt so far as we know.

A peculiarity of the larvae is that they favor the deeper pools and feed and hide among the dead leaves covering the bottom. This renders collecting rather a tedious task and makes it easy to overlook them on a surface examination because they rarely come to the top and do not stay there long. The pupae, however, are always at the surface, as in allied forms.

Aëdes triseriatus Say

The Tree-Hole Mosquito

DISTRIBUTION AND CHARACTERIZATION

[United States east of the Rocky Mountains. In New Jersey 665 females have been trapped.]

Small or medium sized, with black, unbanded legs and beak; sides of thorax silvery white, grayish on dorsum, leaving well defined central stripe, which becomes wide posteriorly. Abdomen black, with white lateral marks, encroaching upon dorsal part at bases of apical two or three segments. Patches on sides of thorax larger and whiter than in any other species.

DESCRIPTION OF THE ADULT

This mosquito varies considerably in size, ranging from 4–6 mm. (.16–.24 inch) long, excluding proboscis, which is 2–2.5 mm. long. Occiput almost entirely covered with grayish white scales; proboscis black, without marks or rings; palpi in female normal, dark brown or blackish, with terminal joint very small, bluntly pointed at apex and flat at base. In male palpi black, slightly dilated toward apex, with steel blue sheen; basal joint long and slender, central short, and together they reach tip of proboscis. Terminal joint very short, only a little longer than half length of central. Fan-like tufts small and scant. Antennae of both sexes brown, with plumes of male paler.

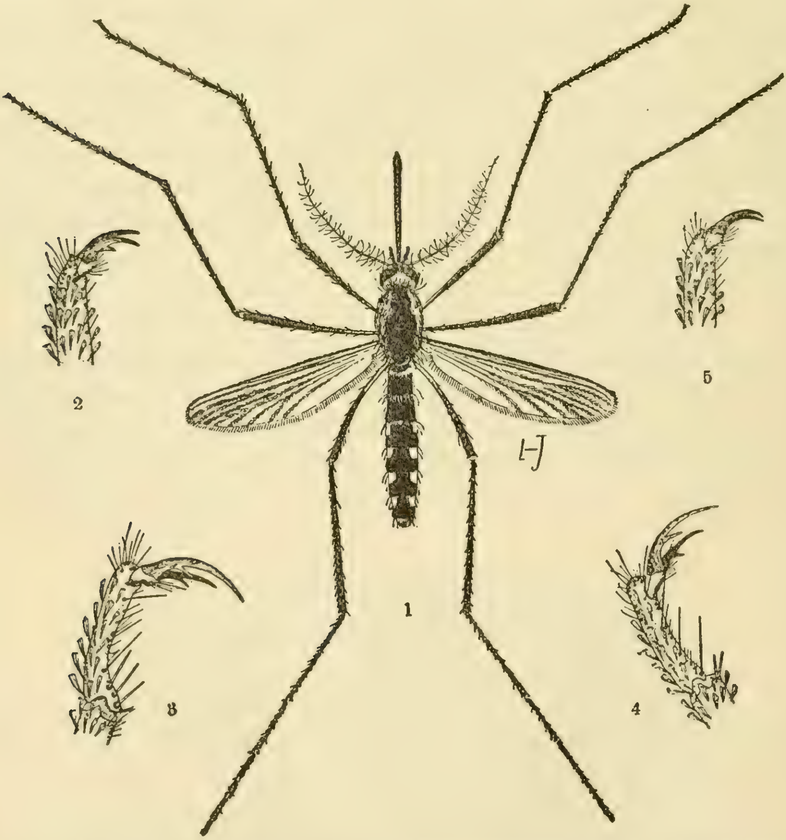


Fig. xl. Adult of tree-hole mosquito. *Aëdes triseriatus* Say. (After John B. Smith.) 1, female adult; 2, anterior claws of same; 3, anterior, 4, middle and 5, posterior claws of male (all enlarged).

Dorsum of thorax grayish white and has broad black band in center, becoming wide and rounded posteriorly. Pleura chestnut brown, almost covered with patches of silvery white scales. Femora black, yellowish beneath and with whitish spot at knee; tibiae black, paler beneath; tarsi wholly black. Claws of male anterior and middle tarsal joints unequal in size, larger evenly curved, with single median tooth, smaller almost straight with median tooth slightly nearer base; claws of posterior tarsal joints equal and simple. Claws of female equal on all feet; those of anterior and middle tarsal joints single-toothed, posterior simple like male.

Abdomen black, with brown hairs on apical margin of anterior segments, extending backward over those following. Beneath creamy white, with pure white basal marks extending up sides and coming well upon dorsal surface in posterior segments; apical segment yellowish. In male white marks sometimes cross abdomen as narrow basal bands.

HABITS OF THE ADULT

This is rather a handsome species and one that is rarely found outside of woodland or its immediate vicinity. Records of captures of adult or early stages indicate that it occurs throughout the state.

It is one of the species that winters in the egg stage, either under water on in a place where water is likely to come in early spring. The adult lays its eggs as near to the surface of the water as possible, at the very edge of the vessel or cavity selected for a breeding place, and these eggs hatch, after a suitable period for development, when they become covered with water.

The earliest date that I have for adults is June 1, when the species was the common form found on the dams around the cranberry meadows at Lahaway, and from that date until October adults were taken in some parts of the state. It is not a common mosquito, but is easily captured, never indoors, but on porches surrounded by trees. The species bites readily and hard. It is no traveler, probably never moving farther from its place of birth than is necessary to find a place for oviposition. It does not fly normally until evening.

DESCRIPTION OF THE LARVA

Thorax broader than long, slightly angulated at sides. Six rather short lateral tufts, two smaller on anterior margin and two very small on dorsum, near anterior margin. Abdominal segments subquadrate in anterior part, becoming elongated posteriorly up to segment seven, and giving larva very disproportionate appearance. Each segment has four

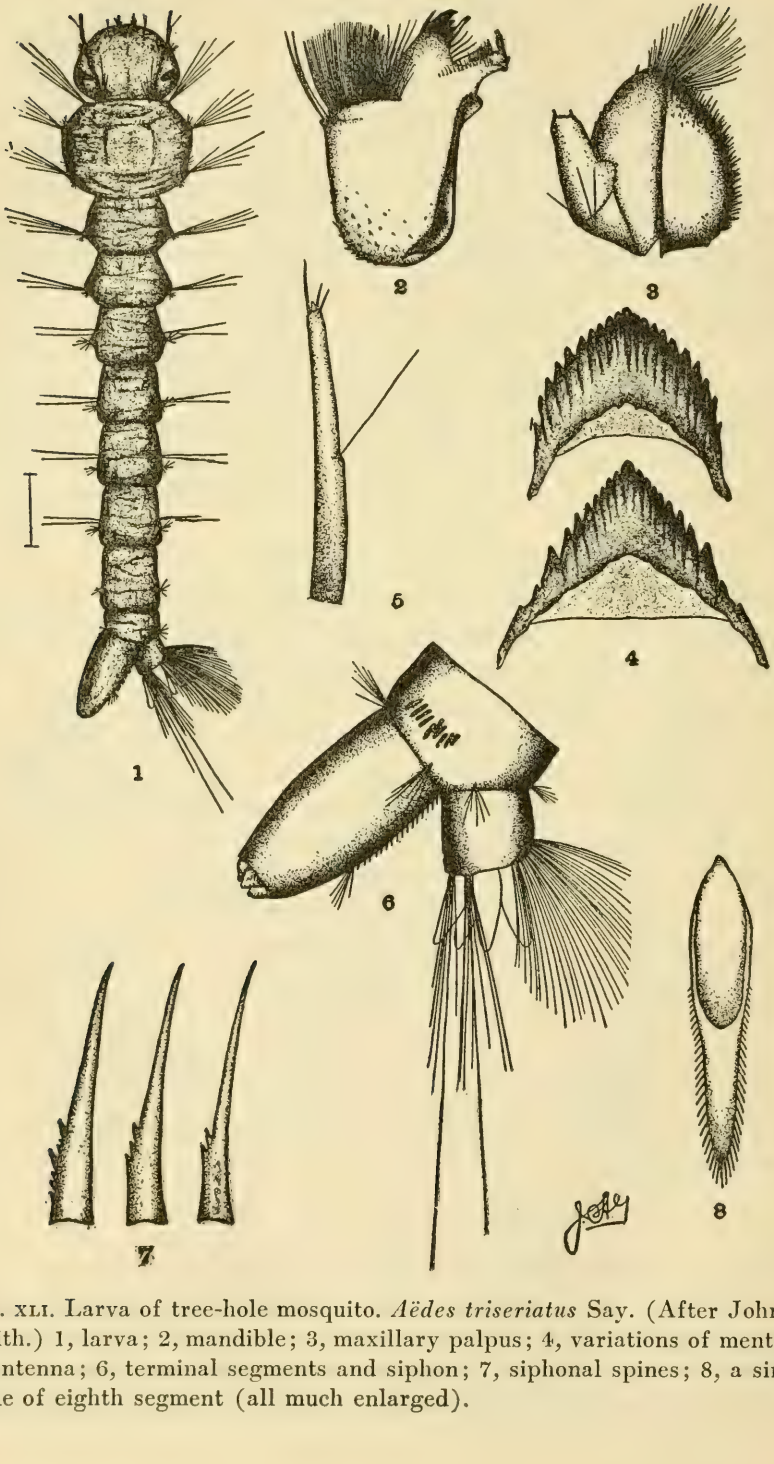


Fig. xli. Larva of tree-hole mosquito. *Aëdes triseriatus* Say. (After John B. Smith.) 1, larva; 2, mandible; 3, maxillary palpus; 4, variations of mentum; 5, antenna; 6, terminal segments and siphon; 7, siphonal spines; 8, a single scale of eighth segment (all much enlarged).

short hair tufts on dorsal surface and several others at sides, in addition to long lateral hairs. These have four or five hairs on each tuft on anterior two segments, two each on following up to segment six; seventh with small tufts only. Eighth segment very short, with eight to thirteen scales arranged in single irregular rows on each side. Individual scale much elongated, with fringing of short hair at sides and apex. Anal siphon dark brown, short and stubby, with double row of spines, from fifteen to twenty-one in each row; small teeth extend upward from base of individual spines. Tuft composed of two hairs terminates each row. Ninth segment about as wide as long, with saddle same color as siphon. Ventral brush moderate in size; consists of eight or ten tufts of four or five hairs each; each dorsal tuft has one very long hair. Anal gills short, about same length as ninth segment.

HABITS OF THE EARLY STAGES

Unusually long, slender wriggler, easily recognizable by that character as well as contrasting dark head and tail; is rather deliberate in movements, usually, and has little of the jerky wriggling that fits the proper name to mosquito larvae in general. It has also the habit of forming a loop, bringing its head almost or quite into contact with the anal siphon and then allowing itself to sink slowly to the bottom. In a jar containing a number of the larvae this habit may be observed at almost any time. Some other species of *Aëdes* do this occasionally; but with *triseriatus* it seems to be a fixed habit. So, the wriggler seems to be able to remain below the surface for quite a long time, sometimes lying quiet, sometimes feeding among the bottom fragments.

The earliest record for the larva is May 9, 1903, the last for the year on September 3. All these collections were made in holes in trees and stumps, and such cavities when water-filled are, without doubt, the normal breeding places for this species. A few examples were taken at New Brunswick in a little woodland brook broken into disconnected pools during the summer, and a full brood from an iron kettle that had been half buried in sand, was partly filled with chips, and almost hidden in the grass at Lahaway. These are the only records of finding them elsewhere than in tree cavities.

This larva, in appearance, is nearer like that of *Aëdes aegypti*, the yellow fever mosquito, than any other of those that occur in New Jersey. Whether this indicates a closer relationship than the adults seem to show and, whether at a pinch, *triseriatus* might do the work of *aegypti* in transmitting the yellow fever, are interesting speculations.

Development is slow, especially when the larvae are removed from the water in which they lived; in fact unless they are nearly full grown they rarely develop at all. The pupal period ranges, even in midsummer, from four to seven days.

[This species when present in numbers has proved to be a very annoying biter.]

Aëdes trivittatus Coquillet
The Three-Striped Mosquito

DISTRIBUTION AND CHARACTERIZATION

[United States from Massachusetts to Texas and in Mexico and Central America. In New Jersey 3,683 females have been trapped.]

It is recognizable by three black, longitudinal stripes with pale yellow background on dorsum of thorax. Legs and beak unbanded, wings unspotted, abdomen has white lateral marks which often cross dorsum at base of segments.

DESCRIPTION OF THE ADULT

Medium sized, body exclusive of beak measuring 5–5.5 mm. (.20–.22 inch); beak 2.5 mm. long or almost half length of body. Head is covered with pale yellowish or grayish scales, darker at sides; proboscis black, without marks; palpi in female black, with terminal joint small, bluntly pointed at apex and flat at base. In male black, without rings, and shaped like those of *A. canadensis*. Antennae brown in both sexes with basal joint of male yellow. Thorax pale yellow with three black, longitudinal stripes on dorsum, central not reaching posterior margin of mesonotum; pleura dark brown with patches of grayish white scales; legs black; under sides of femora pale yellow. Claws of male in anterior and middle tarsal joints unequal in size, larger with median and basal tooth, smaller with a single tooth near base. Claws of posterior tarsal joint equal, each with single median tooth slightly nearer base. In female claws alike on all feet, equal and with one tooth in center of each like posterior ones of male.

Dorsum of abdomen black, venter whitish, white extending up sides at base of segments and upon dorsum, at front angles of posterior segments. These lateral marks often continue narrowly across abdomen, especially in males.

HABITS OF THE ADULT

This is another woodland mosquito, and one which has not, up to the present time, been found in towns or even on porches of buildings

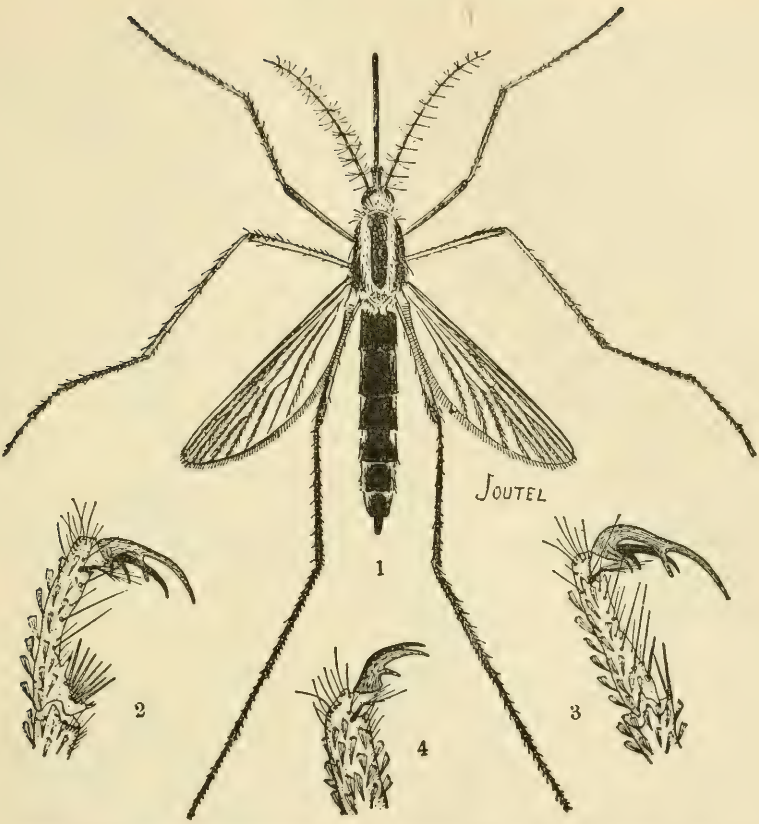


FIG. XLII. Adult of three-striped mosquito. *Aëdes trivittatus* Coq. (After John B. Smith.) 1, adult female; 2, anterior, 3, middle and 4, posterior claws of male (all much enlarged).

surrounded by trees. It has never been found indoors anywhere. The species breeds in some numbers on the ridge back of South Orange. Outdoor captures were made at Trenton, Chester, Summit, Deckertown, Lake Hopatcong, Jamesburg, and the Great Piece meadow. None of these localities are south of the red shale except the Jamesburg locality. All the collectors report that this mosquito is fierce in its attack, but not one was really bitten. Since the insects seemed to tackle low—they rarely came above the knees—the collectors' clothing protected them.

DESCRIPTION OF THE LARVA

Stout, robust, measuring 7–7.5 mm. (.28–.30 inch), to tip of ninth abdominal segment. Body dark gray, with exception of head, siphon, and anal segment. Head rather small, one-third wider than long and evenly rounded in front; in color yellowish with large dark brown blotches which give predominating shade. From anterior part of vertex arise four single hairs, each from separate pit; pits so arranged as to form square, narrower in front; small tuft of four or five hairs at the base of each antenna. Antennae short, evenly tapered apically, yellow, becoming very dark brown toward apex; surface set with rather large spines with very small ones intermingled. Tuft, consisting of eight or ten hairs, situated on shaft slightly below middle. Apex has one long spine, two shorter ones, and small joint, all articulated. Eyes are normal, usually with broad, pale yellow ring. Rotary mouth brushes pectinated on apical third of the more central hairs. Mentum triangular with slightly curved sides of fifteen small teeth each. Mandible has small spines on dorsal surface of base, and maxilliary palpus has moderate apical tuft, rather large basal joint and patches of hair over surface.

Thorax large and stout, with two transverse depressions and smaller transverse wrinkles on dorsum. Sides angulated, each angle giving rise to long hair tufts; two very small hair tufts on anterior margin.

Abdominal segments chunky, anterior two broad, with four or five hairs in each lateral tuft; segments four to seven subquadrate, with two hairs to lateral tuft, except seventh, which has small tufts only. Lateral combs of eighth segment have each fourteen to twenty-two scales. Single scale broad, with rather long acute barb and several smaller ones on sides, becoming shorter toward base. Anal siphon short, about two and one-half times as long as its width at base, dark brown, almost black, with the valves slightly dilated, so as to flare at tip. Spines composing double row curved, with two or three teeth at base, terminal spine sometimes without teeth. From thirteen to eighteen spines in each row. Ninth segment almost square, completely ringed by chitinized saddle same color as siphon. Ventral brush moderate, with two or three small tufts below barred area. Double dorsal tufts normal, each with very long hair as usual. Anal gills short, about same length as ninth segment.

HABITS OF THE EARLY STAGES

Very little is actually known concerning the early stages, full grown larvae and pupae only being at hand. It is probable that the species winters in the egg stage, and that it is not an early species. The larvae were first taken during the last days of June from pools in the woodlands back of South Orange, in company with *A. vexans* and *P. ferox*, and additional material obtained July 2 showed the same combination of species. Collections made August 11 and 12 in the Hatfield swamp

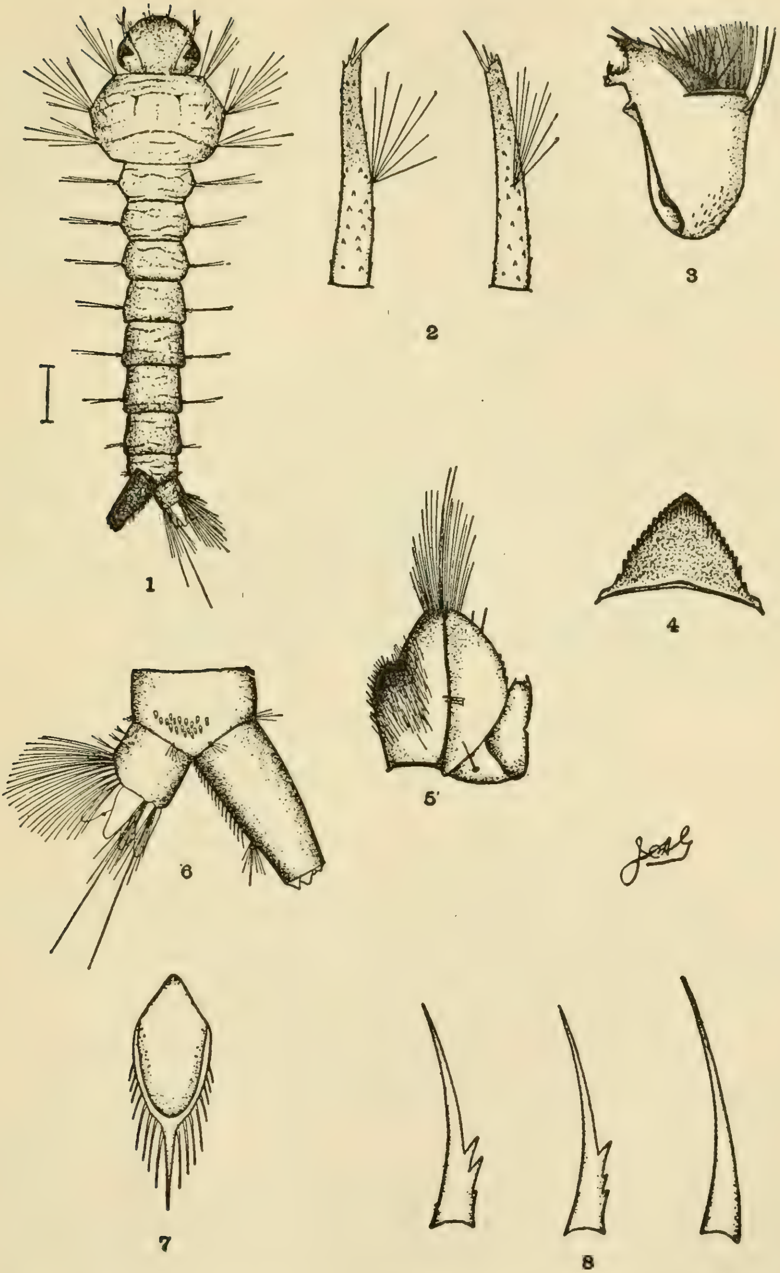


FIG. XLIII. Larva of three-striped mosquito. *Aëdes trivittatus* Coq. (After John B. Smith.) 1, larva; 2, antennae; 3, mandible; 4, mentum; 5, maxillary palpus; 6, terminal segments and siphon; 7, a single scale of eighth segment; 8, siphonal spines showing variation (all enlarged).

turned out a few more examples mingled with *vexans* and that completes the record. As compared with the other larvae that of *trivittatus* was always rare and only a very few examples were obtained for preservation. It seems to be one of those species in which the larvae develop very evenly, for only the full grown wrigglers and pupae were collected. The breeding pools were the usual depressions occurring in woodland; kept moist by shade and small springs, so as to fill readily during a heavy rain and kept up by the same factors long enough to bring even the slow-growing larvae to maturity. Nothing is definitely known as to the length of any period.

MISCELLANEOUS GROUP

[The Miscellaneous Group includes many species not at this time of economic importance. Such species as *Psorophora ciliata Fabricius,* the largest mosquito occurring in New Jersey, is not economically important because of its limited numbers, others because they breed in remote places and do not move much into populated territory. Nevertheless, a knowledge of them is necessary because conditions may so change as to render them economically important.]

Aëdes implacabilis Walker
The Red-Backed Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northeastern United States. This mosquito is recorded from Plattsburg, New York, larvae April 24, 1905 (H. G. Dyar); Dublin, New Hampshire, May, June, 1909 (A. Busck); Springfield, Massachusetts, April 28, 1903 (F. Knab); Wilbraham, Massachusetts, June 4, 1903 (F. Knab); Mount Tom, Massachusetts, May 6, 1903 (F. Knab). Reported also from Orange Mountains and New Brunswick, New Jersey (Morse). Trap records from 1932 to 1936 inclusive indicate no collections of this mosquito.

It seems probable that *Aëdes implacabilis* has a wider range than indicated by these localities. Its distribution seems northern, and it is probably due to chance only that no specimens have appeared in collections from Canada. This species has been referred to by several American authors under the name *punctor.*

Medium sized with dark brown thorax bearing two median brown lines. Abdomen black with broad basal white bands; legs black with bronzy reflections.]

DESCRIPTION

Howard, Dyar, and Knab (14) give the following description:

"*Female.* Proboscis rather long, subcylindrical, uniform; labellae conically tapered; vestiture black; setae on the labellae minute, outstanding. Palpi short, about one-fifth as long as the proboscis, black, the setae moderate, bristly. Antennae filiform the joint subequal, rugose, pilose, black, second joint slightly thickened and paler; tori subspherical, with a cup-shaped excavation, luteous brown, some white scales on inner side; hairs of whorls sparse, moderate, black. Clypeus rounded triangular, prominent, black, nude. Eyes black. Occiput black, scales on vertex narrow, on the sides broad, yellowish white on vertex, with some golden brown scales each side of middle line, dull white on the

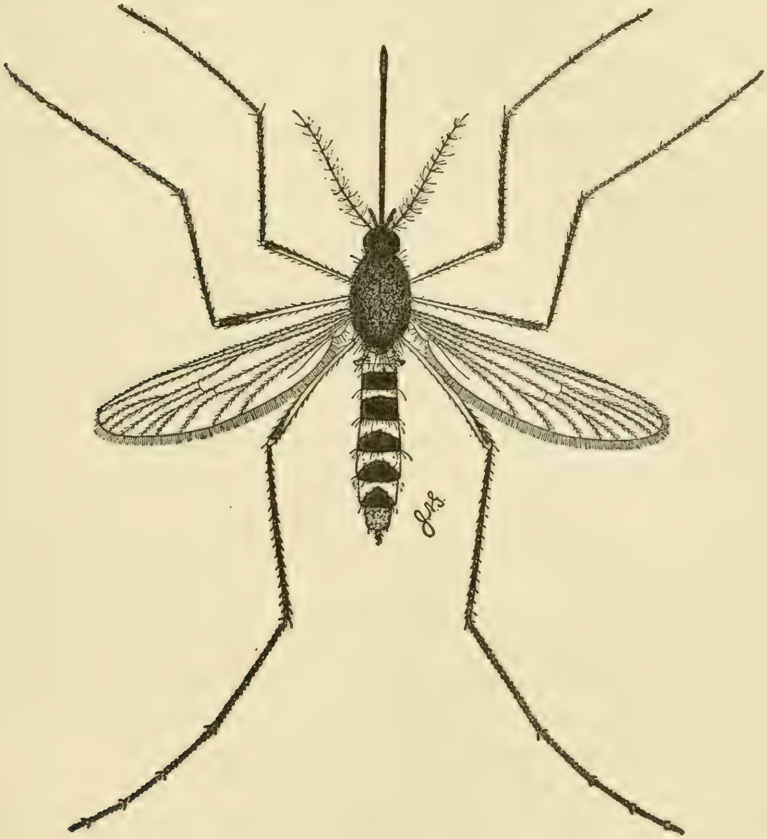


FIG. XLIV. Adult of red-backed mosquito. *Aëdes implacabilis* Walk. (After John B. Smith.)

sides, and an ill defined lateral black patch, many short, erect, forked pale scales on nape; bristles along margins of eyes black, those projecting between the eyes pale.

"Prothoracic lobes elliptical, remote dorsally, black, clothed with narrow golden brown scales and dark bristles. Mesonotum black, evenly clothed with narrow, curved scales, bright bronzy brown, an indistinct, slightly darker median stripe of smaller scales, scales over antescutellar space yellowish white. Scutellum trilobate, black, clothed with narrow, curved, yellowish white scales, each lobe with a group of pale bristles. Postnotum elliptical, prominent, blackish, nude. Pleurae brown, coxae luteous, with rows of pale bristles; clothed with patches of elliptical flat white scales, the prothoracic epimera with narrow curved bronzy brown scales like those on mesonotum.

"Abdomen subcylindrical, tapering posteriorly; dorsal vestiture black, with moderate, white, basal segmental bands, broader posteriorly, which widen to triangular patches on the sides; first segment with white scales and numerous fine pale hairs; venter whitish scaled, the last two or three segments with black, apical lateral patches. Cerci black.

"Wings moderate, hyaline; petiole of second marginal cell shorter than its cell, that of second posterior cell about the same length as its cell; basal cross-vein distant about its own length from anterior cross-vein; scales dull brown, the outstanding ones broadly linear. Halteres whitish, knobs dark.

"Legs moderate; femora yellowish white scaled below with black ones above and a black ring before tip; knees white; tibiae largely pale scaled below, black above, tips black; tarsi black scaled, the basal joint with many pale scales beneath becoming fewer outwardly, terminal joints entirely black. Claw formula, 1.1–1.1–1.1.

"Length: Body about 4.5 mm., wing 4 mm.

"*Male.* Proboscis long and slender, straight, black scaled. Palpi nearly as long as proboscis, blunt at tip; end of long joint and last two joints somewhat swollen; vestiture black; hairs on the end of long joint and on last two joints long, dense, black with a yellowish reflection in certain lights. Antennae plumose, the last two joints long and slender, pilose, the others short, blackish; hairs of whorls long, dense brownish black with yellow luster. Coloration similar to the female. Wings narrower than in the female, stems of the fork-cells longer, vestiture less abundant. Abdomen elongate, depressed, with dense, long and pale lateral ciliation; dorsal white segmental bands broader and more expanded laterally than in the female, last segment entirely white-scaled. Claw formula, 1.1–1.1–1.1.

"Length: Body about 5 mm.; wing 4 mm.

"Genitalia: Side-pieces more than twice as long as wide; apical lobe well developed, prominent, continued narrowly along side-piece to basal lobe, which is slightly squarely prominent and bears numerous setae with tubercular bases and a stout hooked spine with an attendant group of small spines. Clasp-filament slender, moderate, slightly expanded in middle, notched towards apex, and bearing a few fine setae, a long articulated terminal spine. Harpagones with a moderate, slender, columnar base bearing a rather short, articulated, medianly widened, terminal filament. Harpes elliptical, concave, curved, inner margin thickened and revolute, tip pointed and curved outward. Unci approximate, revolute, forming a small basal cylinder. Basal appendages approximate, bearing four or five stout terminal setae.

"*Larva, Stage IV.* Head rounded, narrowed before eyes, slight notch at insertion of antennae, front margin arcuate. Antennae cylindrical, curved, spined all over; tuft moderate, before middle; four terminal spines of various lengths, two shortly subapical, a short thick digit. Eyes transverse, pointed. Dorsal head-hairs single, ante-antennal tufts in threes or fours. Mental plate shortly triangular; apical tooth broad, roundedly incised as if formed of three fused teeth, eleven side-teeth become larger basally, the last one small and remote. Mandible quadrangular, with small spines near base; two filaments before tip; an outer row of cilia form a collar; eleven filaments on outer edge; dentition of four teeth on a process, the first longest; a filament and two unequal teeth before; a broad filament and six feathered ones within, unusually large; process below furcate, with patches of hair; a pointed basal angle, with four long hairs within; a long row of hairs at base. Maxilla elongate hemispherical, divided by an oblique suture; inner half with rows of hairs, a large tuft at vertex; outer half with a band of hair, two filaments next the suture toward apex and a spine on the other side; palpus short, with four small digits and a central elevation. Thorax wider than long; hairs moderate. Abdomen rather stout, the anterior segments shorter; lateral hairs single on segments three to six; tracheal tubes broad, band-shaped. Air-tube stout, about three times as long as wide; pecten usually evenly spaced, occasionally with some of the terminal teeth somewhat detached, reaching less than half the length of tube, followed by a single tuft of two or three hairs; single spine long, slightly widened at base, with two small branches

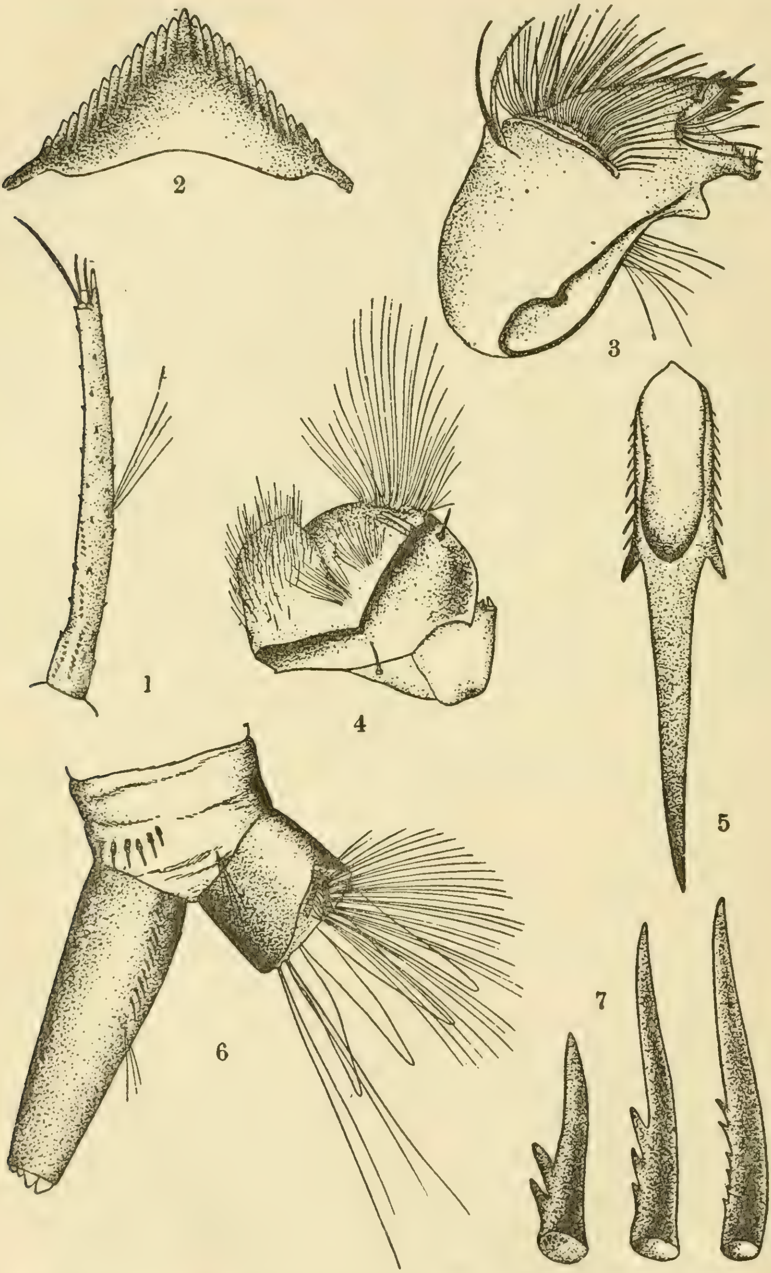


Fig. xlv. Larva of red-backed mosquito. *Aëdes implacabilis* Walk. (After John B. Smith.) 1, antenna; 2, mentum; 3, mandible; 4, palpus; 5, scale from eighth segment; 6, terminal segments with siphon; 7, siphonal spines (all enlarged).

rather far out. Lateral comb of eighth segment of a very few scales in a line; single scale elliptical, fringed with short spinules and with one very long stout terminal spinule. Anal segment longer than wide, ringed by the plate; dorsal tuft a pair of long hairs on each side; ventral brush well developed, confined by the plate; anal gills moderate, tapered.

"The larvae appear in the early spring, hatching from the overwintering eggs. There is but a single annual generation. The larvae occur mixed with the other early spring species in woodland pools and marshes, often when ice is still present. Mr. Knab and Dr. Dyar collected nearly fully grown larvae from a marsh by standing upon ice at its edges and dipping under the ice, where the larvae had taken refuge. The females live for two or three months in the woods, and soon become much worn, being then indistinguishable from other species of *Aëdes* with similar habits."

Aëdes atlanticus Dyar and Knab

The Silver-Striped Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Southern Atlantic States. In New Jersey no specimens have been trapped.]

Moderate sized black mosquito, characterized by broad silvery gray stripe through center of thorax. Legs and beak unbanded, wings unspotted, abdomen black, with lateral white marks which partly show on dorsum of apical segments.

DESCRIPTION OF THE ADULT

Ordinary build, 5–6 mm. (.20–.24 inch) long, exclusive of beak; head brown, with large patch of white scales in center of occiput extending between eyes, which have faint whitish border on posterior margin. Proboscis black throughout, one-third length of body, or about 2 mm. long. Female palpus normal in form, black, terminal joint obsolete; in male black, shape and fans as in *A. canadensis*, longer than proboscis by last joint. Antennae in both sexes very dark brown, basal joint in female yellowish, plumes in male light brown.

Thorax black with longitudinal silvery gray stripe in center of dorsum, which narrows somewhat toward front, has sharply defined edges and does not quite reach anterior margin. Pleura light brown, becoming very pale beneath, and have small patches of white scales. Legs black, with deep blue sheen, under sides of tibiae yellowish, on femora creamy white. Claws of male anterior and middle tarsal joints unequal in length, larger with median and basal tooth, smaller with single tooth near base. On posterior tarsal joint claws equal, each with single tooth short distance from base. In female claws alike on all feet, equal in size and, like posterior ones of male, have single tooth near base.

Abdomen black above, with purplish reflections, pale yellow beneath, segments marked with lateral white spots extending upon dorsal surface at front angles of apical segments.

HABITS OF THE ADULT

This is distinctly a handsome species, readily recognized by the broad silvery stripe on the back. It was originally described from South America, but occurs throughout New Jersey, though nowhere in large numbers. Little is positively known of the habits of the adults, and that little is not especially to its discredit. It bites, of course, when its haunts are invaded, but it lives in low swampy woods where rubber boots are desirable at most periods and where few persons ever go. There is absolutely no record of its capture in towns or houses, hence it cannot be included among the pestiferous forms.

DESCRIPTION OF THE LARVA

Very robust, when full grown 6–7 mm. (.24–.28 inch) long, excluding anal siphon. Head dark brown, with darker diffused blotches on vertex, widest at eyes, tapering anteriorly and somewhat flattened in front. Four hairs on anterior part of vertex, each arising from separate pits, one pair in advance of other; tuft of five or six hairs at base of each antenna. Antennae short, not quite half length of head, thickest at basal third and terminated by one long spine, three smaller ones and small joint. Hair tuft of moderate length issues from shaft at about middle, surface set with small, stout spines. Rotary mouth brushes have simple and pectinated hairs, pectinated ones short and curved in more central part and obscured by long simple ones. Mentum triangular, with fifteen or sixteen small teeth on each side of apex. Mandible normal; maxillary palpus short and broad, with moderate apical hair tuft and rather large chunky, basal joint. Patches of hair, some feathered, on surface of palpus.

Thorax angular, wider than long, with moderate hair tufts at each of lateral angles and two smaller tufts on anterior margin. White, with median black portion becoming wide anteriorly.

Abdominal segments one to six almost black, anterior two with lateral

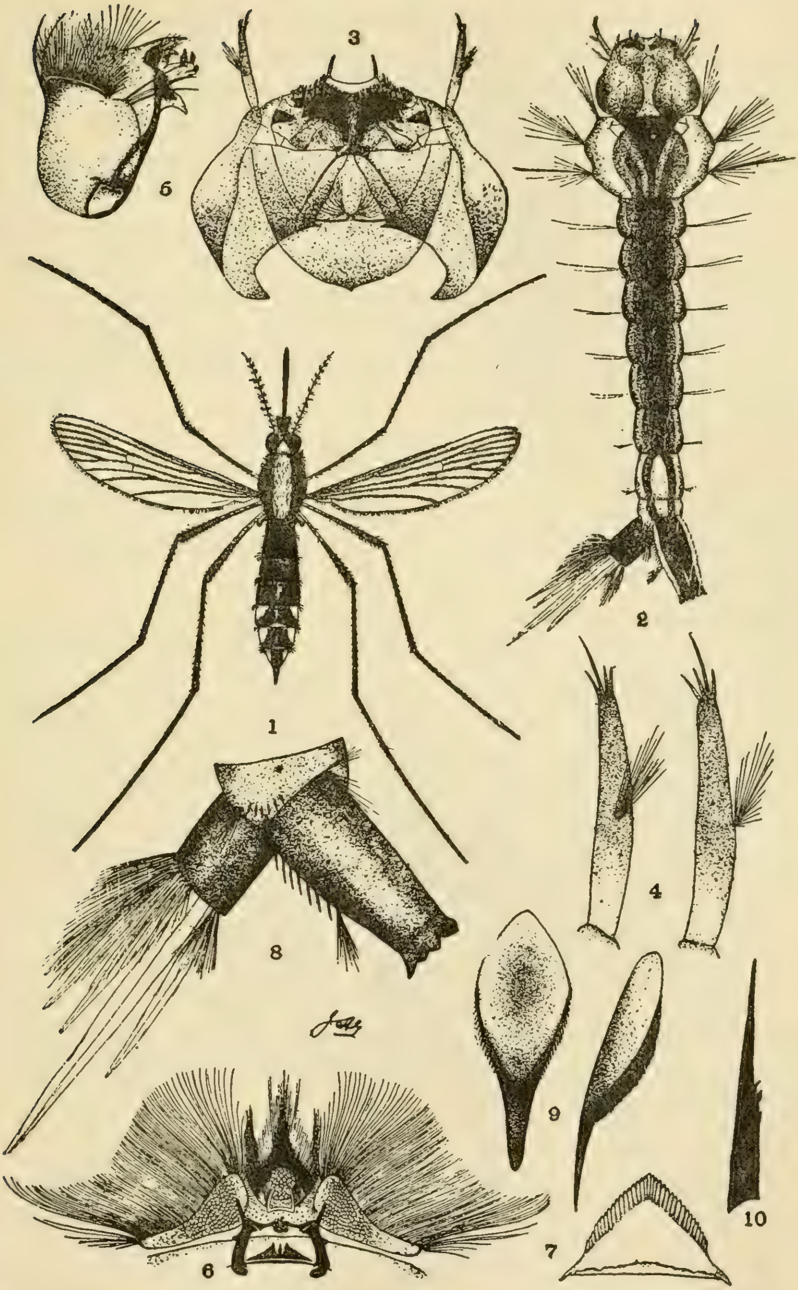


FIG. XLVI. Adult and larva of silver-striped mosquito. *Aëdes atlanticus* D. & K. (After John B. Smith.) 1, female adult; 2, larva; 3, larval head from beneath; 4, antennae; 5, mandible; 6, mouth brushes; 7, mentum; 8, terminal segments with siphon; 9, scales of eighth segment from below and side; 10, siphonal spine (all enlarged).

tufts of four or five hairs each, following ones with two hairs to each lateral tuft, diminishing in length posteriorly. Seventh and eighth segments white, with short tufts only; eighth with regular row of five or six scales on each side; individual scales shaped as in Fig. XLVI. Anal siphon dark brown, almost black, about twice as long as broad, slightly dilated near base, valves also a little dilated so as to flare at tip. Two rows of spines consist of five or six each, single spines not curved, essentially like figure, though there is some variation. Ninth segment a little longer than broad, same color as siphon. Ventral brush moderate, with few small tufts below barred area. Double dorsal tuft short, each part with one very long hair. Anal gills long and slender, tapering to point, without obvious tracheae.

HABITS OF THE EARLY STAGES

The suggestion that the species winters in the egg stage is made because it appears constantly associated with *canadensis* and *vexans*, of which this is true.

The earliest actual collection date is July 29, 1903, when full grown larvae and pupae were collected. From the pupae six males and four females emerged July 30, and five females August 1. Some of the larvae pupated July 31 and adults emerged August 3, a period of three days. The latest collections were made September 30 at Livingston Park, and adults from this lot were all out before the middle of October.

From this record a continuous breeding is indicated, the number of existing pools, determining the number of broods. Though there was an abundance of rain near New Brunswick during the summer, the woods were, nevertheless, unusually dry, a result of the very severe, continuous winter which kept moisture out of the ground and allowed the water to run off or to evaporate in the spring before the surface was in an absorbent condition. The result was that when rains did come they were completely absorbed and not enough was in the ground at any time to allow standing surface pools.

Aëdes atropalpus Coquillet
The Rock Pool Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Locally throughout eastern United States and is recorded from Arizona and New Mexico. In New Jersey 113 females have been taken in traps.]

It is closely allied to *A. canadensis*, the tarsi being ringed with white on both sides of the joints, except in the last two of the hind feet and the last three of the fore and middle feet; the last joints of the hind pair are wholly white. The beak is unbanded, the wings unspotted, the thorax golden yellow with a blackish central stripe and the segments of the abdomen have narrow, irregular, white bands at their bases.

DESCRIPTION OF THE ADULT

Small, of slight build, the body measuring, exclusive of beak, 3.5.–4.5 mm. (.14–.18 inch). Head back of large black eyes covered with whitish scales; patch of black scales on each side which sometimes mix with those of top. Proboscis black, long, slender, 2.5–3 mm (.10–.12 inch) long. Palpi in female black, fourth joint small, oblong, with obtuse apex, one or two long bristles; one specimen examined showed minute

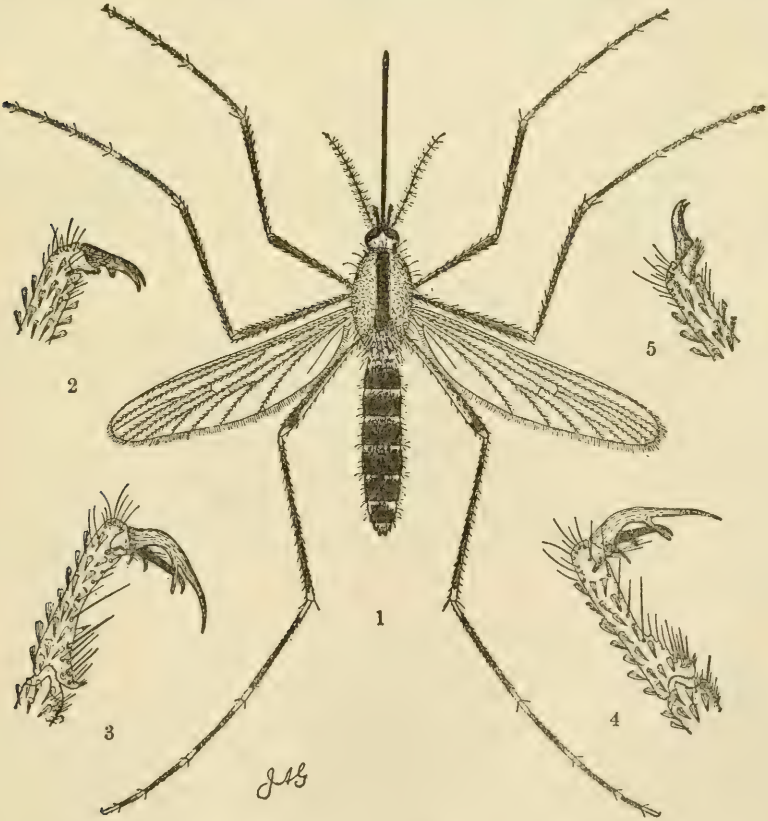


Fig. xlvii. Adult of rock pool mosquito. *Aëdes atropalpus* Coq. (After John B. Smith.) 1, female adult; 2, anterior claw of same; 3, anterior, 4, middle and 5, posterior claws of male (all much enlarged).

fifth joint. In male palpi black, two-thirds length of proboscis, terminal two joints less than half length of basal joint; a few short hairs toward apex represent fan-like tufts. Female antennae brownish black, short, but with the usual number of joints; male antennae dark brown, joints ringed with white, plumes grayish brown.

Dorsum of thorax covered with golden yellow scales, has blackish central stripe which becomes diffused in posterior portion. Pleura dark brown, with small patches of dirty white scales. Legs black, femora yellowish underneath, except near apex, extreme apex white. Tibiae and first and second tarsal joints of hind legs white at both base and apex, third and fourth tarsal joints white at base only; last joint wholly white. In front and middle tarsi bands much reduced, first being the only one white at both ends, others white at base, becoming more or less obsolete in last two joints. Claws of male anterior and middle tarsal joints unequal in size, larger with median and basal tooth, smaller with single median tooth near base. Posterior claws equal and simple. In female claws equal on all feet, those of anterior and middle tarsal joints one-toothed, posterior simple as in male.

Abdomen purplish black with whitish bands at base of segments, becoming broad at sides until wholly white beneath. In female bands very narrow and irregular, sometimes wholly wanting; in male, broader, well defined and always present.

HABITS OF THE ADULT

No observations have been made by any member of the force upon the larva of this species, which will be almost certainly found in such situations as occur along the shores of the Delaware River in Warren County and of some other streams in the rocky section of the state.

Dr. Harrison G. Dyar, who has published the life history from observations made in New Hampshire and along the banks of the Potomac, says that the adults are very troublesome on and about the river and bite freely.

DESCRIPTION OF THE LARVA

When full grown 7–9 mm. (.28–.36 inch) long, of pale grayish white except head, siphon and ninth segment. Head rounded, almost as broad as long, blackish brown, with four rather short hairs arising from separate points in anterior part of vertex; small hair tuft composed of four or five hairs at base of each antenna. Antenna rather short, almost as broad at tip as at base, uniformly dark brown and sparsely set with small spines; apex has one long spine, three smaller ones and usual small

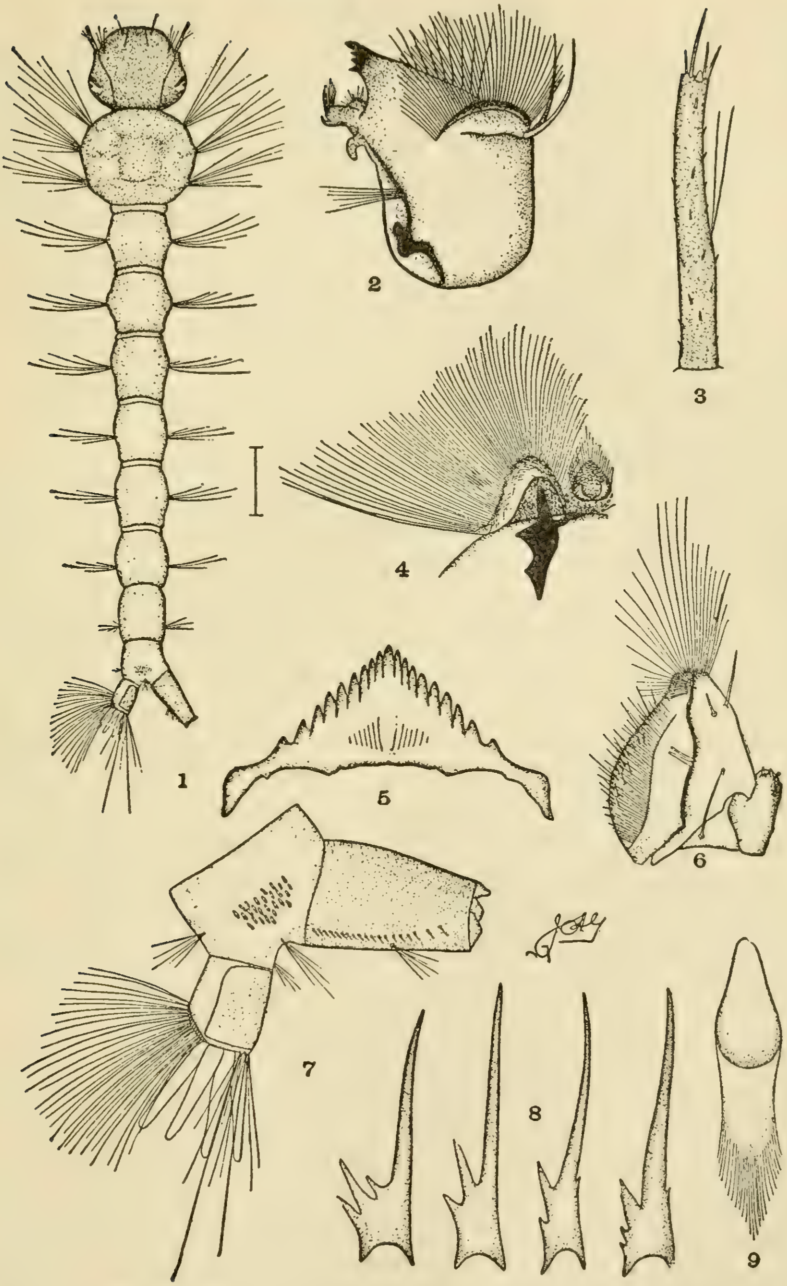


FIG. XLVIII. Larva of rock pool mosquito. *Aëdes atropalpus* Coq. (After John B. Smith.) 1, larva; 2, mandible; 3, antenna; 4, mouth brush; 5, mentum; 6, maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from eighth segment (all much enlarged).

peg. Hair tuft issues from shaft slightly below middle, and consists of but two fine hairs, which do not reach apex. Eyes occupy part where head is widest and are very small, consisting of crescent-shaped piece and very small detached portion in concavity. Whole surrounded by small ring of yellowish white, in strong contrast with dark colored head. Rotary mouth brushes yellowish brown with more central hairs pectinated at tips. Mandible normal, but rather broad. Maxillary palpus tapers toward apex, has moderate apical tuft and medium sized, stout, basal joint. Mentum broadly triangular, almost three times as broad as long at base, with nine or ten teeth on each side, small at apex, becoming larger toward base.

Thorax a little larger than head, rounded and with slight angles at sides, each angle giving rise to rather long hair tufts.

Abdominal segments from one to seven greatly elongated, very disproportionate to small thorax and comparatively large head; lateral tufts have each three to five hairs, diminishing in size posteriorly, seventh with small hair tufts only. Eighth segment has lateral patches of scales, from twenty-five to thirty-five in each patch; single scales very small, rather broad and with fine, long fringes confined to broad apex. Anal siphon dark brown, about twice as broad as long and evenly tapered toward apex. Double row of spines extends almost to apex and consists of seventeen to twenty-one each, individual spines broad at base, with two or three large teeth and sometimes small one on opposite side. Siphonal tuft in center of siphon, slightly nearer apex. Only species where spines exceed tuft; usually it terminates row. Ninth segment very small, dorsal half saddled by dark brown chitinized plate; ventral brush moderate and usually confined to barred area, though rarely small tufts below it; double dorsal tuft normal, each with one long hair. Anal gills slender, a little longer than ninth segment.

HABITS OF THE EARLY STAGES

According to Dyar the eggs in fall are laid in patches on the rock side of the pot holes where the larvae occur, usually at a time when the water is low, and the winter is passed in that condition. They begin to hatch in March, but irregularly, and the larvae grow slowly. From adults matured late in April eggs were obtained after two weeks and these were scattered loosely over the surface of the water, not adherent to the sides, in patches. The eggs are black, elliptical, the ends round pointed, coarsely reticulated. Those laid in spring hatched in three days and there are, probably, several broods during the season. My observations agree with the following from Dyar: "The larvae are rather deliberate in their motions and habitually remain long below the water. They can be seen browsing along the sides of the jar well below the surface; feeding on the green *Protococcus* that grows there. Occasionally they rise and push the breathing tube through the surface film for a few seconds, but they do not remain hanging there, but shortly descend to resume browsing. The anal processes are long and well supplied with trachae, which permits the larvae to remain long under water."

Aëdes aurifer Coquillet
The Golden-Scaled Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northeastern United States west to Ontario and Minnesota. In New Jersey one specimen has been trapped.]

Characterized by long, black, unbanded legs, femora yellow inwardly, unbanded beak and uniformly colored abdomen. Golden yellow scales on sides of thorax, leaving black central band on disc; posterior part of disc also has yellow scales arranged in longtitudinal lines.

DESCRIPTION OF THE ADULT

Medium size, not very robust; body 5.5 mm., or not quite one-quarter inch long; beak about one-half length of body; wings when expanded measure 10 mm., or .40 inch across. Sides of head taken up by large black eyes which almost meet on top of anterior part. Vertex back of eyes clothed with golden yellow scales. Beak black, palpi in female short, four-jointed, two central joints moderately long, bristle-like set with scales; apical joint small, slightly longer than wide, covered with fine short hair, basal segment destitute of scales, but with a few hairs on apical part. Male palpi longer than beak, black, with some hairs of fan-like tufts, whitish, and stalk of basal segment with slight angulation near middle. Antennae of male plumose, blackish, with twelve cup-like joints surrounded with circle of fine long hair, and two long, slender terminal segments set with fine short hair; base of apical one with circle of six long bristles. Female antenna has usually twelve long, narrow joints covered with short hair, each set with six long bristles at base.

Thorax has undefined black central band, broken in posterior part by irregular lines of golden yellow scales and edged with scales of same color which extend for short distance down sides and intermingle with patch of white scales. Legs all black, with femur and inner side of tibia yellowish. In male anterior claw-joint excavated inwardly, and set with

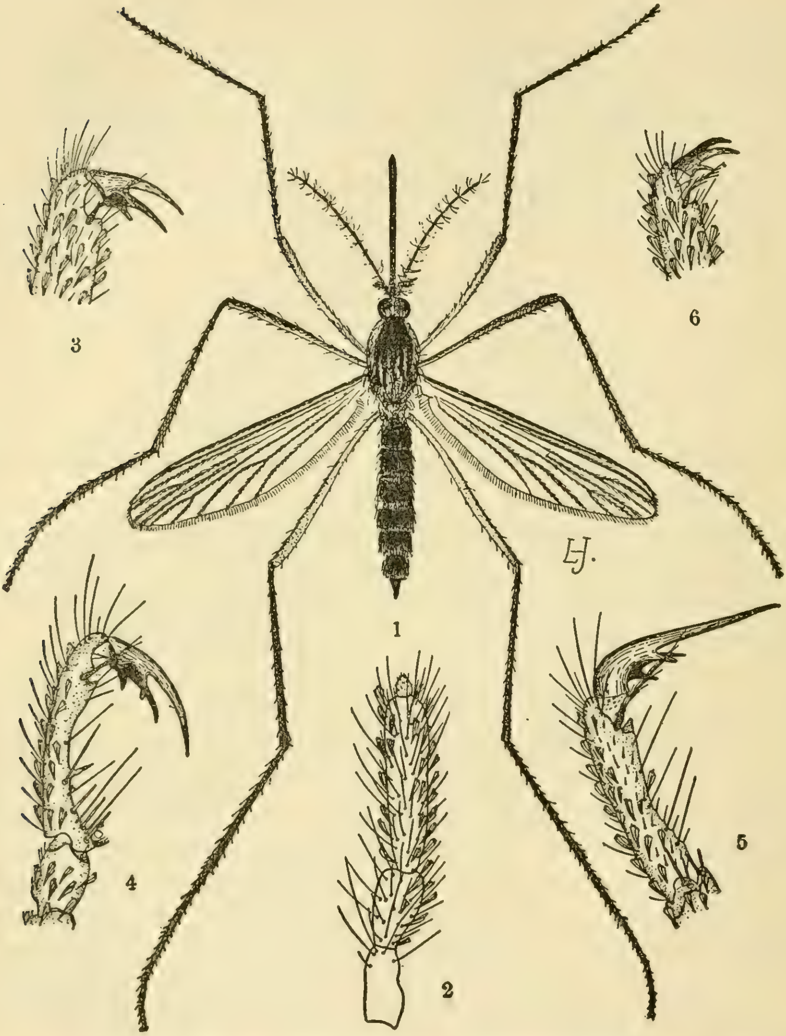


Fig. xlix. Adult of golden-scaled mosquito. *Aëdes aurifer* Coq. (After John B. Smith.) 1, female adult; 2, palpus of same; 3, anterior claw of same; 4, anterior, 5, middle and 6, posterior claws of male (all enlarged).

moderately long, bristle-like hairs; inner claw much longer than outer, both have single median tooth slightly near base. Claw-joint of middle tarsi curved a little inwardly; with one very long claw, sharply curved at base and long, straight, tapering point, and one rather short claw; both with long slender tooth near base. Hind claw-joint long, with two very small, single-toothed claws of equal size.

Claws of female alike on all feet, of equal size and with one tooth a short distance from base.

Abdomen black on dorsum, with faint white lines separating segments, and pale yellow on venter.

HABITS OF THE ADULT

Though *aurifer* is by no means common anywhere, it is one of the most bloodthirsty species we have. It has never been found far away from its breeding places and does not enter houses, but does fly for some distance at night, and is not so closely confined to the woods as *canadensis*. If its haunts are entered during the day it attacks fiercely and fearlessly.

The earliest date for adult *aurifer* is April 23, the latest for larvae is May 10, from which the adult was bred May 13. Adults were taken as late as July 24, yet bloodthirsty, and occurred in considerable swarms during the last days of June. This would indicate an adult life period of nearly three months, much longer than we have been inclined to credit them with.

DESCRIPTION OF THE LARVA

When full grown, measures 7–9 mm. (.28–.36 inch) to end of ninth segment. Specimens usually grayish or brownish black, though, rarely, rusty almost brick colored. Head transversely elliptical, nearly as large as thorax, broadest immediately behind eyes. Two tufts, situated close together, each composed of two hairs, arise from each side of head slightly lower than antennae; one large tuft directly at base of each antenna. Eyes moderate in size, antennae white, tipped with black, almost half as long as head is broad, thickest near base, tapering slightly to about middle, then curved inwardly, becoming very narrow distally, apex with three long spines, one short one, and little joint. Tuft consists of from six to ten long hairs situated above middle, at obtuse angle formed by curve. Surface of antennae set with small stout spines, concolorous with antenna. Rotary mouth brushes large and composed of simple hairs. Mentum broadly triangular, with eleven or twelve teeth on each side of apex. Mandible normal and best described by reference to figure. Maxillary palpus clothed with soft, fine hair, arranged in patches, has a large, long tuft at apex, little joint at its base, with small articulated spines at blunt tip.

Thorax transverse, edges of segments so marked as to form three angles with tubercles from which arise tufts of long hair. Two smaller tufts are on cephalic margin.

Abdominal segments one to six, inclusive, have lateral tufts of long hairs, while segments seven and eight have tufts much reduced in length.

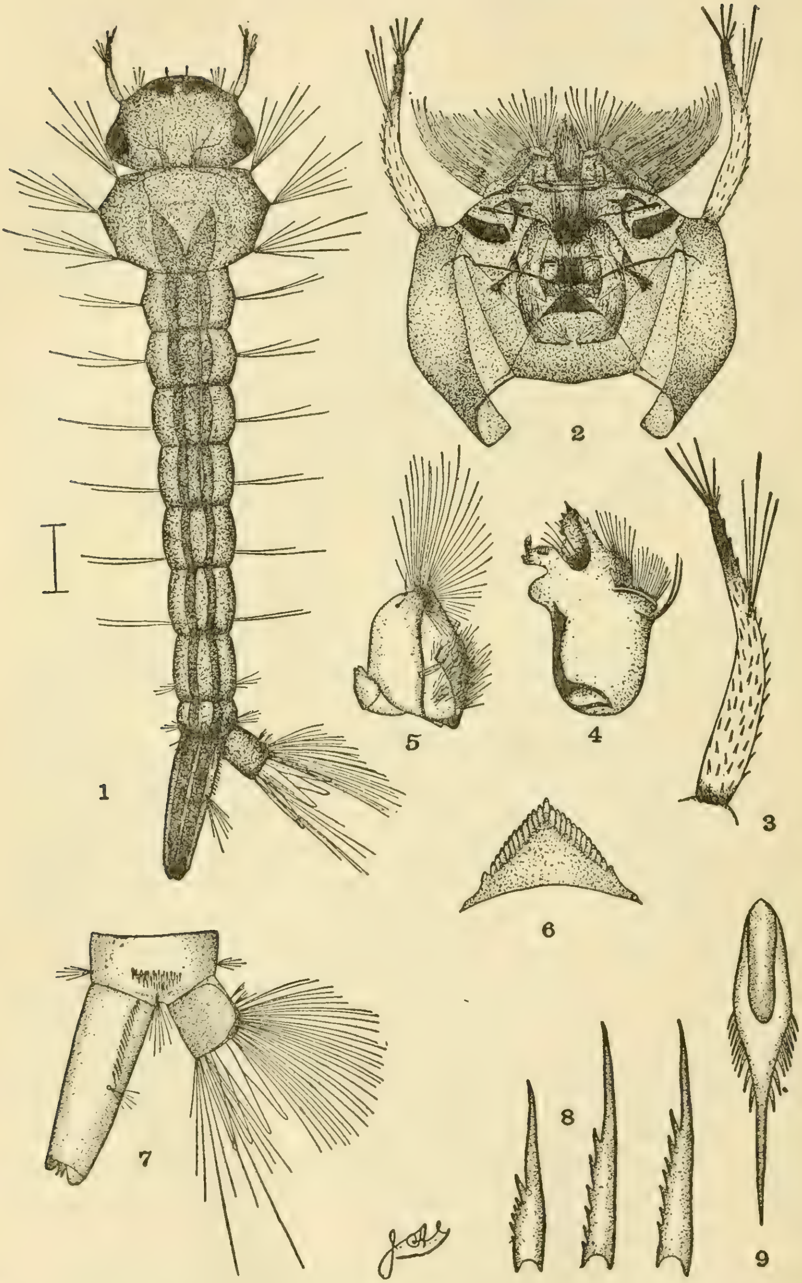


Fig. L. Larva of golden-scaled mosquito. *Aëdes aurifer* Coq. (After John B. Smith.) 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal segments with siphon; 8, siphonal spines showing variations; 9, a single scale of eighth segment (all enlarged).

Combs of eighth segment have from eighteen to twenty-eight fringed scales in each patch. Anal siphon three and one-half times as long as broad, with straight sides, does not taper much toward apex. Lateral rows of spines consist each of fourteen to twenty toothed spines. Individual spine much broadened at basal half, with five to seven teeth. Ninth segment little longer than wide, with usual double tuft, each having one very long hair on dorsal part of apical margin. Barred area on ventral part, with ten to twelve tufts of five or six hairs each. Anal gills moderately long, without obvious tracheae.

HABITS OF THE EARLY STAGES

Practically all our knowledge of this species indicates a general distribution in the state, but a rare occurrence at any point. All who have taken the larvae have found them associated with that of *canadensis* and have found them comparatively rare. They do not hug the edge of the pool so generally as do some of the other species, but favor tufts of grass, rushes or vines several feet from shore. No *aurifer* larvae have been collected with the earliest *canadensis,* and from such data as I have at hand it seems that the eggs begin to hatch during the early days of March and that the larvae grow quite rapidly at first, as though they might produce the earliest adults. But they linger in the last stage, and the first pupae require from five to nine days to mature.

Eggs of *aurifer* have not been obtained by me; but there seems little doubt that they are laid like those of *canadensis,* though probably different in form. The water is drawn from the bogs before the *aurifer* adults disappear, hence the eggs must be laid in the bog mud, where they rest until they become water covered again in late fall and hatch in the spring following. I have no evidence that there is more than one brood of this species. The pupa is recognizable from that of *canadensis* by its decidedly larger size and white air-tubes.

Aëdes cinereus Meigen
The Little Smoky Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Canada and United States from the Atlantic Ocean to British Columbia but is less abundant southward to Arkansas. In New Jersey ninety-seven specimens have been trapped.]

Small dark brown with black unbanded legs and beak; thorax evenly brown, sometimes with faint longitudinal black lines, abdomen black, usually with narrow bands at base of segments, broadest in central portion.

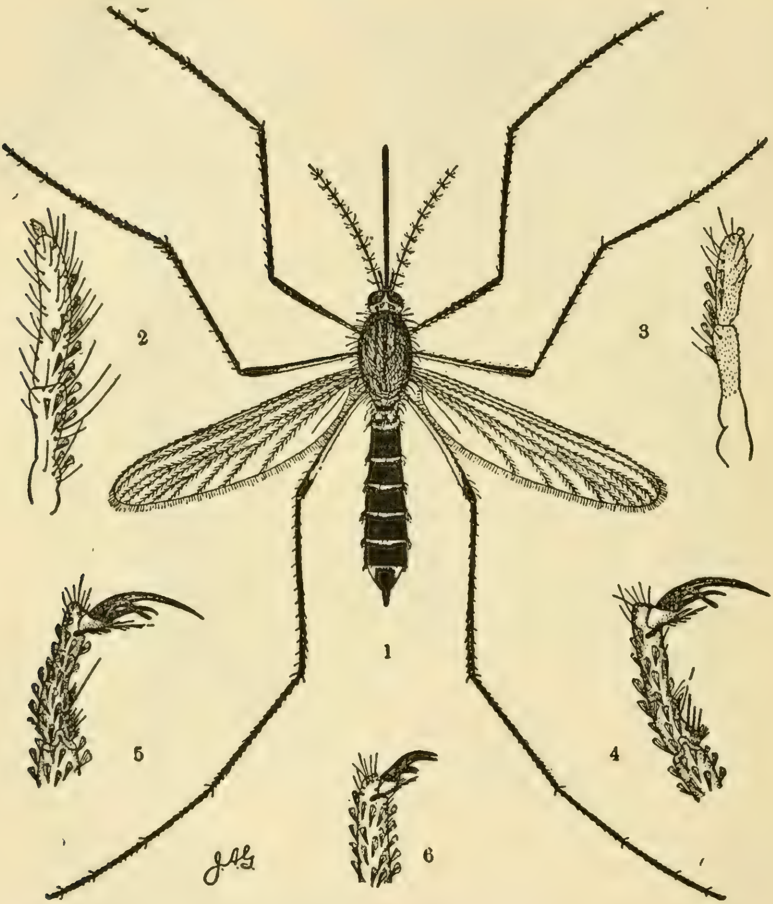


Fig. li. Adult of little smoky mosquito. *Aëdes cinereus* Meig. (After John B. Smith.) 1, female adult; 2, palpus of same; 3, palpus of male; 4, anterior, 5, middle and 6, posterior claws of male (all enlarged).

DESCRIPTION OF THE ADULT

Small mosquito, body measuring 3.5–4 mm. (.14–.16 inch); beak just about half length of body. Head covered with creamy yellow scales; in female two large patches of brown scales in central part of occiput converging anteriorly; in male these patches much reduced and widely separated. Proboscis black without bands or rings. Palpi in female short, set with moderately long bristles; three-jointed, second joint longer than first, and terminal joint very small, though longer than broad and pointed at apex. Palpi in male about three-fourths length of those of female, three-jointed, second joint shorter than first, terminal joint minute and circular in outline, first and second joints set with few bristles toward apex. Antennae dark brown in female, with three basal joints pale yellowish; male antennae banded brown and white, first joint very large, second swollen, plumes brownish.

Thorax evenly reddish brown, sometimes with one or more faint blackish lines down center; pleura pale brown with small irregular patches of dirty white scales. Legs wholly black, except femora, which are creamy white beneath, with very small white dot at knee. Claws of male anterior and middle tarsal joints unequal in size, larger with long, blunt median tooth, smaller simple. Male posterior claws and all those of female equal, rather slender, with single median tooth near base. Clothing and venation of wings similar to those of *Culex*, but lateral scales long and slender.

Abdomen black, above, with narrow creamy basal bands; in female these bands wide in center, becoming narrow toward sides, except in seventh segment, which usually has narrow band, broad at sides. In male bands always wide, broadest at extreme sides, often forming lateral margin to apical segments. Sometimes basal bands wholly obsolete, but this occurs in females only. Venter thickly clothed with pale yellow scales.

HABITS OF THE ADULT

Practically nothing is known of the adult in nature. Although it has been bred from a number of widely separated localities between the Black River Swamp in the north and Lahaway in the south, yet it has been taken on the wing once only, at Metuchen, on May 7. It can hardly be considered a pest.

DESCRIPTION OF THE LARVA

Full grown measures 7–8 mm. (.28–.32 inch) in length, excluding the anal siphon and greatly resembles ordinary *Aëdes canadensis* or *vexans;* but is much more slender than either. Light gray to dark slate gray, except head and anal siphon. Head broader than long, pale yellow or darkly infuscated, often has brown crescent-shaped mark and several smaller spots in center of vertex. Four small hair tufts of four or five hairs each arise from anterior part of vertex, two larger tufts at base of antennae. Antennae moderately long, rather slender, tapering evenly toward apex, with tuft well below middle, composed of but five or six hairs which do not reach apex; surface set with small spines, thickly at

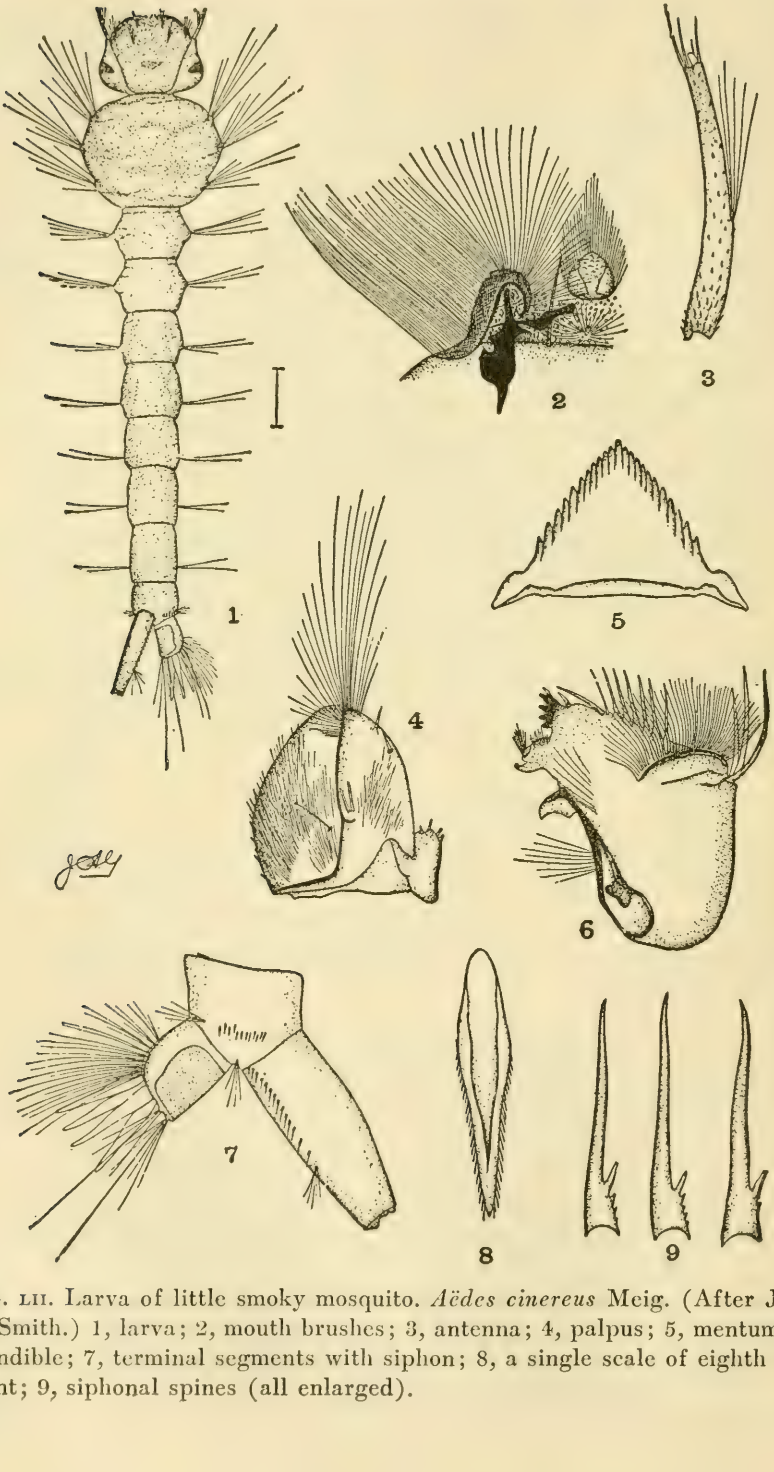


Fig. lii. Larva of little smoky mosquito. *Aëdes cinereus* Meig. (After John B. Smith.) 1, larva; 2, mouth brushes; 3, antenna; 4, palpus; 5, mentum; 6, mandible; 7, terminal segments with siphon; 8, a single scale of eighth segment; 9, siphonal spines (all enlarged).

base, sparsely toward tip, apex has three long spines, short one and small joint. Rotary mouth brushes composed of simple hair, mentum almost equilateral triangle with nine to thirteen small teeth on each side of apex. Maxillary palpus normal, apical tuft moderate, basal joint small and stout, surface thickly covered with patches of hair and some small spines. Mandible normal in form but peculiar by having three curved dorsal spines.

Thorax circular in outline with six lateral hair tufts issuing from acute, darkly infuscated tubercles; no tuft on anterior margin.

Abdominal segments subquadrate on anterior segments, becoming elongated posteriorly, with lateral hair tufts of two hairs each; except first two segments which have four or five hairs to tuft. Eighth segment has short tufts only and bears lateral combs. These consist of twelve scales each, arranged in irregular single row. Scales elongated, with short, fine, lateral hairs on apical two thirds. Anal siphon four times as long as broad, yellow or pale brown, tapering slightly on apical half. Double row of spines has from twelve to sixteen spines in each, apical two separated from rest and from each other; individual spines slender, each with one large tooth and often one to four very small ones below it. Ninth segment considerably longer than broad, with dorsal plate extending lower than middle; double dorsal tuft and ventral brush normal, latter with several small tufts below barred area. Anal gills slender, longer than ninth segment.

HABITS OF THE EARLY STAGES

There is every reason to believe that this species winters in the egg stage; first, because it has been found very early in the larval stage, in company with species which are known to winter that way and, second, because the larva has been found in pools dry during the winter and only filled by the spring rains. The earliest date of larvae collected was April 7, from which adults of this species were obtained April 13. It may be in place here to say that these larvae are so much like others that are found in the same pools early in spring that unless attention is especially directed to them they readily escape recognition. The fact that this species is not a larval hibernate was definitely settled when, on April 15, nearly mature larvae were found in a pool that had been completely dry during the winter. It is fair to conclude from records of capture that there are no late broods.

This is classed among the local breeders; that is, a species which one can count upon finding every year in about the same places; but which does not occur in all bodies of water even under similar conditions.

Aëdes dupreei Coquillet

Dupree's Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Locally in southeastern United States to Central America, Trinidad, and West Indies. Recorded locally from New Jersey. In New Jersey no specimens have been trapped.]

Resembles *Aëdes atlanticus* on small scale; silvery dorsal stripe well defined, becomes wide posteriorly in female; in male diffused. Beak and legs unbanded, wings unspotted, abdomen white-marked laterally, showing slightly on upper side at basal angles of posterior segments.

DESCRIPTION OF THE ADULT

Small blackish, body measuring 2–3 mm. (.08–.12 inch), exclusive of beak, which is about 1.5 mm. long. Occiput covered with silvery white scales; black patch on each side which sometimes mixes with scales of occiput. Proboscis uniformly blackish, palpi in female normal, dark brown, with terminal joint extremely small, circular, covered with fine short hairs. Male palpi brown, shaped like those of *A. canadensis*, except that first joint dilated a little at base and again one-third from base; nearly as long as proboscis. Antennae brown in both sexes, black at base in female.

Thorax deep brown, with silvery white median stripe, which becomes wide posteriorly. In female this stripe well defined, sometimes rather broad; but in male diffused with whitish scales that cover whole mesonotum. Pleura brown. Femora chiefly yellowish, with some brown scales on dorsal surface, tibiae and tarsi blackish brown. In male claws of anterior and middle tarsal joints are unequal, larger with median and small basal tooth, smaller with small tooth near base; posterior claws equal, apical two-thirds at right angles to base, and each with large basal tooth. In female claws alike on all feet, equal, hook-shaped, each with large curved tooth near base.

Abdomen covered with brown scales, black at apices of segments; white beneath, extending up sides, showing slightly on dorsum at basal angles of apical two or three segments.

HABITS OF THE ADULT

Very little is known of this small species, which has never been taken by any of the collectors in the adult stage. In 1904 it was taken only once, in any stage, despite careful search in the localities where it was

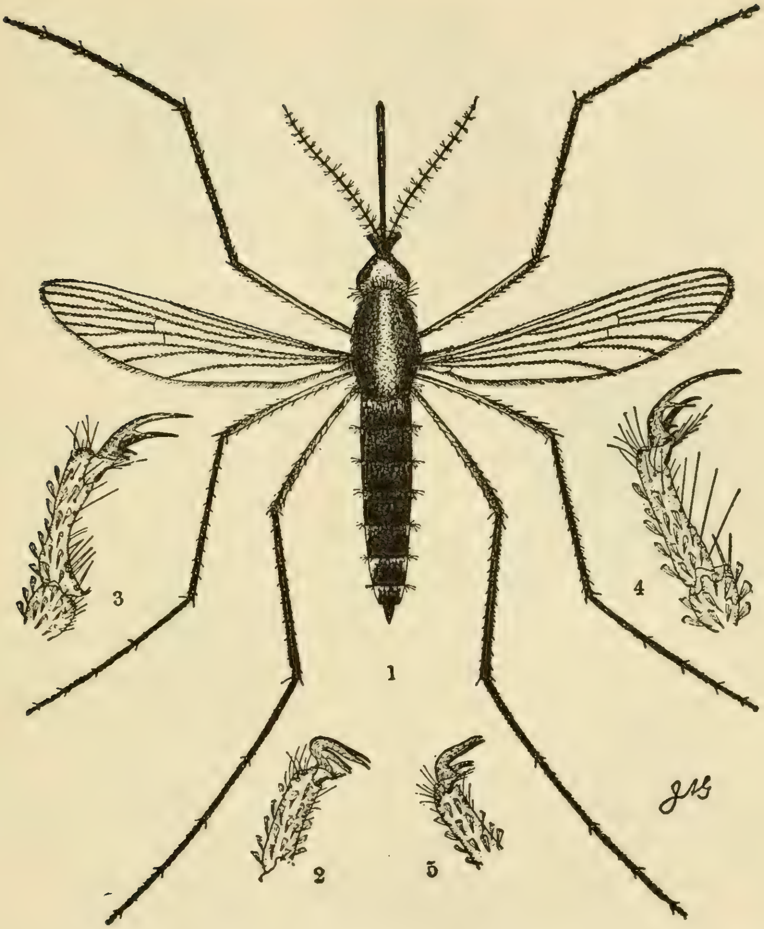


Fig. LIII. Adult of Dupree's mosquito. *Aëdes dupreei* Coq. (After John B. Smith.) 1, adult female; 2, anterior claw of same; 3, anterior, 4, middle and 5, posterior claws of male (all much enlarged).

found in 1903. It is scarcely probable that it bites, and it certainly cannot be classed as a pest in any sense. It was originally taken by Dr. Dupree, of Baton Rouge, Louisiana, and its occurrence in New Jersey was unexpected. Nothing is known of the method of hibernation, nor of the manner in which the eggs are laid.

DESCRIPTION OF THE LARVA

Small, inconspicuous, averaging 5.5 mm. (.22 inch long), exclusive of anal siphon, though specimens rarely 6.5 mm. Dirty white or yellowish, almost transparent, very difficult to see in water; when placed in alcohol becomes darker. Head yellow with faint cloud on vertex, almost twice as broad as long, evenly rounded in front. Six hairs arise from anterior part of head, four in central part, one from base of each antenna. Antennae short, half as long as head, pale yellow. Almost uniform in thickness two-thirds from base, tapers slightly toward tip, where there are four short spines and a small joint; surface sparsely set with small, stout spines. Eyes rather small occupy part where head widest, rotary mouth brushes very dense, hairs pectinated at tip, most obviously so in center of structures. Mandible normal, with few small spines on dorsal part of base. Maxillary palpus short and broad, with rather large apical tuft and large, stout, basal joint. Mentum triangular, with thirteen to sixteen small teeth of uniform size on each side of apex.

Thorax one and one-half times width of head, sides angulated, each angle with moderate cream colored tufts, and two small, two-haired tufts on anterior margin.

Abdominal segments one to seven subquadrate, with two hairs to each lateral tuft. Eighth segment has lateral combs of scales arranged in single regular curved rows. Each row consists of seven to twelve elongated scales, very acute at apex, fringed at sides with short, fine hairs. Anal siphon four and one-half times as long as wide at base and tapers rather evenly toward tip. Small; readily overlooked in living larva. Lateral rows of spines consist each of from nine to thirteen and extend one-third length of siphon from base. Individual spines slightly curved, their apices drawn to long, slender points, bases rather broad with three or four teeth. Ninth segment almost square, completely ringed by chitinized saddle; ventral brush rather large, composed of ten or twelve tufts of hair, confined to barred area; double dorsal tuft small, each tuft with one long hair. Anal gills very long and slender, pointed at apex, lateral margins scalloped, tracheal tubes plainly visible through them.

HABITS OF THE EARLY STAGES

The species when first found in the larval stage in a woodland pool near New Brunswick, July 29, 1903, was at once recognized as distinct by its unusually long anal gills, the very small breathing tube and by its habit of remaining close to the bottom, a very unusual one for a mosquito larva. While in confinement the wrigglers never rose voluntarily to the surface, and when disturbed sailed rather than wriggled upward, descending immediately when quiet was restored. So inconspicuous and transparent are they, that a jar containing them would be set aside as empty unless critically examined, and this, together with their habit of

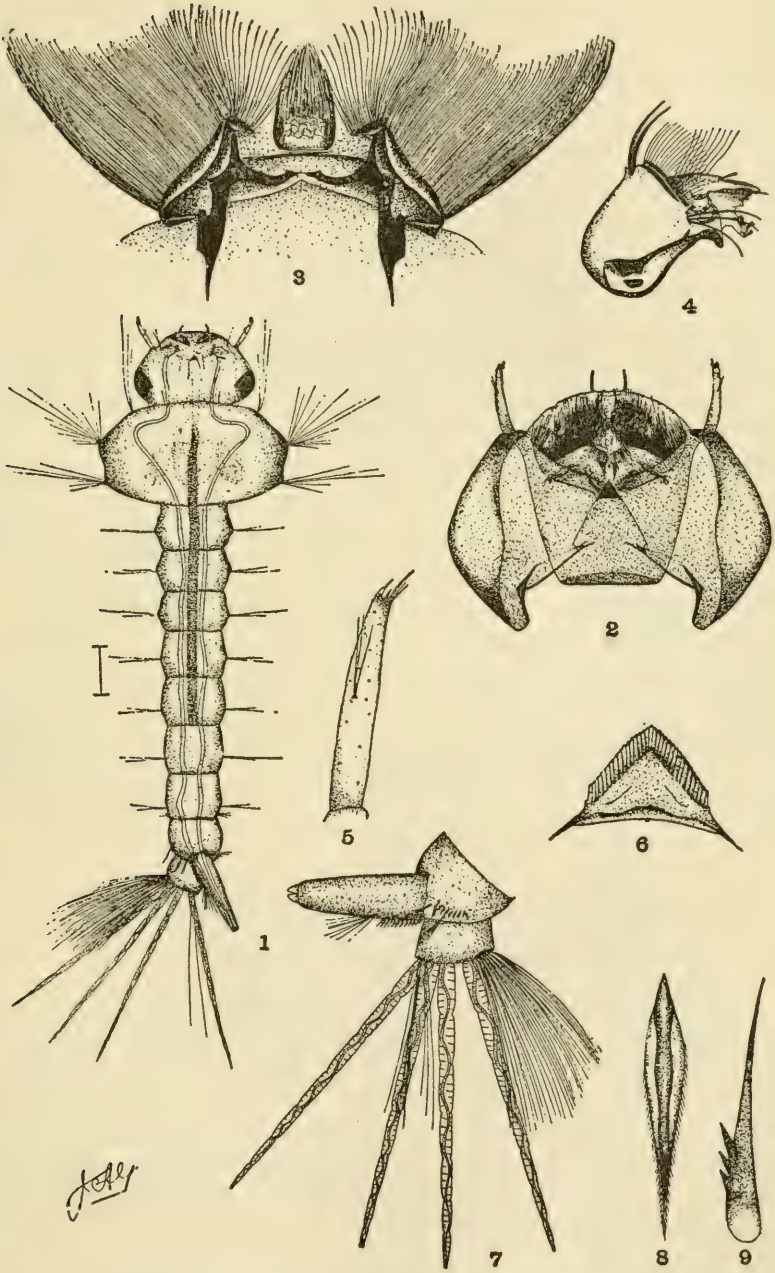


Fig. liv. Larva of Dupree's mosquito. *Aëdes dupreei* Coq. (After John B. Smith.) 1, larva; 2, head from beneath; 3, mouth brushes; 4, mandible; 5, antenna; 6, mentum; 7, terminal segments showing siphon and tracheal gills; 8, scale of eighth segment; 9, a siphonal spine (all much enlarged).

hiding among leaves at the bottom of pools, renders them difficult to secure.

A number of pupae were brought in with the larvae and from these adults of both sexes were obtained. Several larvae pupated and matured, giving an average duration of three days in that condition. The pupa is normal in appearance.

Other collections were made at the same place August 13, when full grown larvae and pupae were obtained, and September 3, when half grown larvae only occurred.

The larvae were found in woodland pools in the Great Piece meadow, September 9 and 10, fully developed and in the pupal stage. Adults were obtained after an average stay of four days in the pupal stage. September 24 half grown larvae were found in the same place; but none of these were brought to maturity. September 29, the larvae were found on the Garret Mountains. It is probable, of course, that the species will be found in other parts of the state where there are low, swampy, dark woodland areas.

The record indicates continuous breeding from the middle of July to the end of September, and it may begin much earlier.

[Howard, Dyar, and Knab (14) speculate that the winter is passed in the egg stage in the soil. They do not hatch with snow water in the early spring. Larvae appear at intervals after rains, eggs hatching whenever conditions are favorable. Females are not attracted to man and do not suck blood.]

Aëdes grossbecki Dyar and Knab

The Scaly-Winged Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from New Jersey to Mississippi. In New Jersey one specimen has been trapped.]

Very large mosquito; jet black tarsi, with well defined white bands at base of joints, broad white bands at base of abdominal segments, black marked thorax and unbanded beak. Wings are spotted but veins heavily ornamented with black and white scales.

DESCRIPTION OF THE ADULT

Large blackish brown, very robust. Body 6–7 mm. (.24–.28 inch) long, exclusive of beak, wings expand about 14 mm. or almost three-fifths inch; beak not quite half length of body. Head whitish in posterior

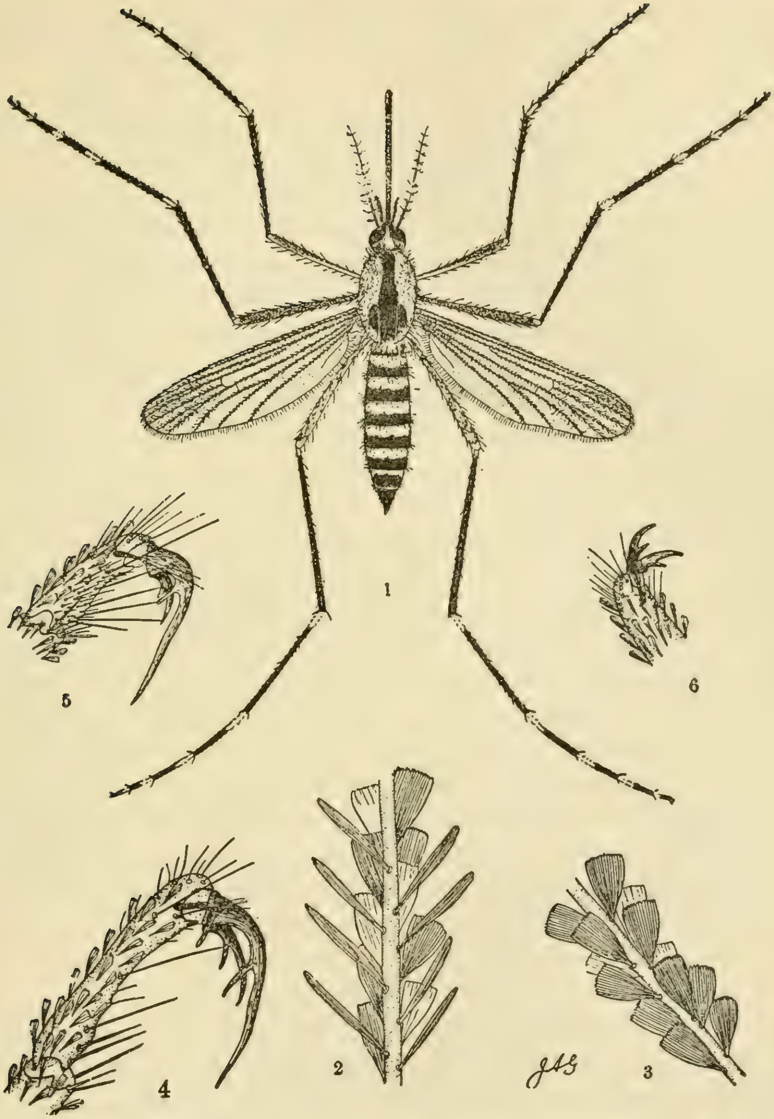


Fig. lv. Adult of scaly-winged mosquito. *Aëdes grossbecki* D. & K. (After John B. Smith.) 1, female adult; 2, part of wing vein near outer margin; 3, same near base; 4, anterior, 5, middle and 6, posterior claws of male (all enlarged).

part, with patches of brown or blackish scales on each side of center; beak black with few scattered pale scales on central and basal portions; palpi in female slender, black, tipped with white, terminal joint small round knob with short spiny hairs. In male brown or blackish, basal joint white near head, with yellow band in center; fan-like tufts brown with yellow hairs at base of second joint and at apex of third joint. Antennae of female dark brown, those of male paler brown with yellow sheen.

Thorax grayish white with dark brown median band, excavated in anterior portion, sprinkled with few golden brown scales. Other brown marks on sides of band, posteriorly separated from it by narrow grayish stripes. Band sometimes light brown anteriorly mixed with gray, giving thorax mottled appearance. Pleura brown with patches of whitish gray scales. Femora have mixed black and yellow scales on upper surface, fewer on posterior side, not collected into spots or bands; apices yellow, almost wholly yellow beneath. Tibiae black except for slight sprinkling of yellow scales, posterior ones yellow at knee. Tarsi black with well defined white bands at base of each joint in hind feet and narrower bands on first four joints of middle and fore feet. Claws one-toothed on all feet of both sexes. Those of anterior tarsal joint in male stout, one about three-fourths length of other, shorter one with tooth nearer base. Claws of middle tarsal joint, one short with tooth at middle and one very long tooth, sharply curved at basal third, situated in inner angle. Hind pair of claws, also all those of female, of equal length, with median tooth slightly nearer base. Wings hyaline, veins densely covered with broad, mixed black and white scales, with many long narrow ones on apical third of wing.

Abdomen black above with few whitish scales intermixed; segments one to six broadly banded with yellowish white at base, segment seven narrowly banded both basally and apically, tending to join at lateral borders, apical segment and genitalia black. On some specimens bands break into black irregularly. Beneath abdomen yellowish.

HABITS OF THE ADULT

This species was originally described from California and was first taken in New Jersey May 8, 1903, at Westville, with a lot of *canadensis*, which were then flying. Later in the season it was taken in a low, swampy woodland near New Brunswick June 28, July 16, and July 28. In 1904 samples were taken in the same woods during the latter part of June and until after the middle of July. They were always associated with *canadensis*, had approximately the same habits of flight and bit readily. They were not found to be especially vicious, however, and their bite was not more severe than that of the other species. No specimens have ever been taken outside of the woods and they are so rare there, that they cannot be regarded as in any way troublesome. Since larvae have been taken near Paterson, it is perhaps a fair conclusion that the species occurs in favorable localities throughout at least the northern half of the state. The period of flight is long, and as we have no indication that there is more than one brood, the period of flight indicates an individual life of about three months.

DESCRIPTION OF THE LARVA

Full grown wriggler measures 12–14 mm. (.48–.56 inch) long, excluding anal siphon, dirty gray, excepting head and siphon, in general build, resembles *Aëdes canadensis.* Head almost as broad as long, widest just below eyes, tapering without curve to beyond base of antenna, flattened in front, light brown in color, with four small black spots near base of vertex. On anterior part of vertex four single hairs, each arising from separate pits; pits so placed as to form square, slightly narrower in front; directly opposite posterior hair, at base of each antenna, small tuft of four or five hairs. Antenna rather short, curved, uniformly brown, surface sparsely set with short, stout spines and numerous small ones scattered on basal half. Tuft of four or five hairs situated at middle, does not reach tip of antenna, which has apex terminated with one long and one short spine, two short bristles and small articulated peg. Eyes moderate size, semicircular, with small detached portion at posterior edge. Rotary mouth brushes thick, composed of hairs pectinated in the more central portion. Mentum triangular about as long as broad, with slightly curved series of from twelve to fourteen small teeth on each side of apex. Mandible normal, set with small spines at base. Maxillary palpus short, very broad, hairs and spines arranged in patches on surface, with a comparatively small apical tuft; basal joint rather large with small, stout spines at apex. Thorax rounded, with rather short hair tufts issuing from slight angles at sides. Anterior margin also, with two short hair tufts. Abdomen long, anterior two segments transversely oblong with lateral tufts of four or five hairs; central and posterior ones lengthened and narrower, with only two hairs to lateral tuft up to segment seven. Eighth segment has lateral patches of from twenty-eight to thirty-four scales, without any regular arrangement; single scale has spines at apex and along sides, apical one largest and longest, other diminishing in size toward base. Anal siphon about four times as long as wide at base and has two series of toothed spines, each ranging from seventeen to twenty-two. Spines black, white-tipped, with teeth not quite reaching middle; common arrangement four teeth to form two pairs. Ninth segment longer than wide, with the two dorsal tufts and ventral row of tufts present, as usual. Tracheal gills only slightly longer than ninth segment.

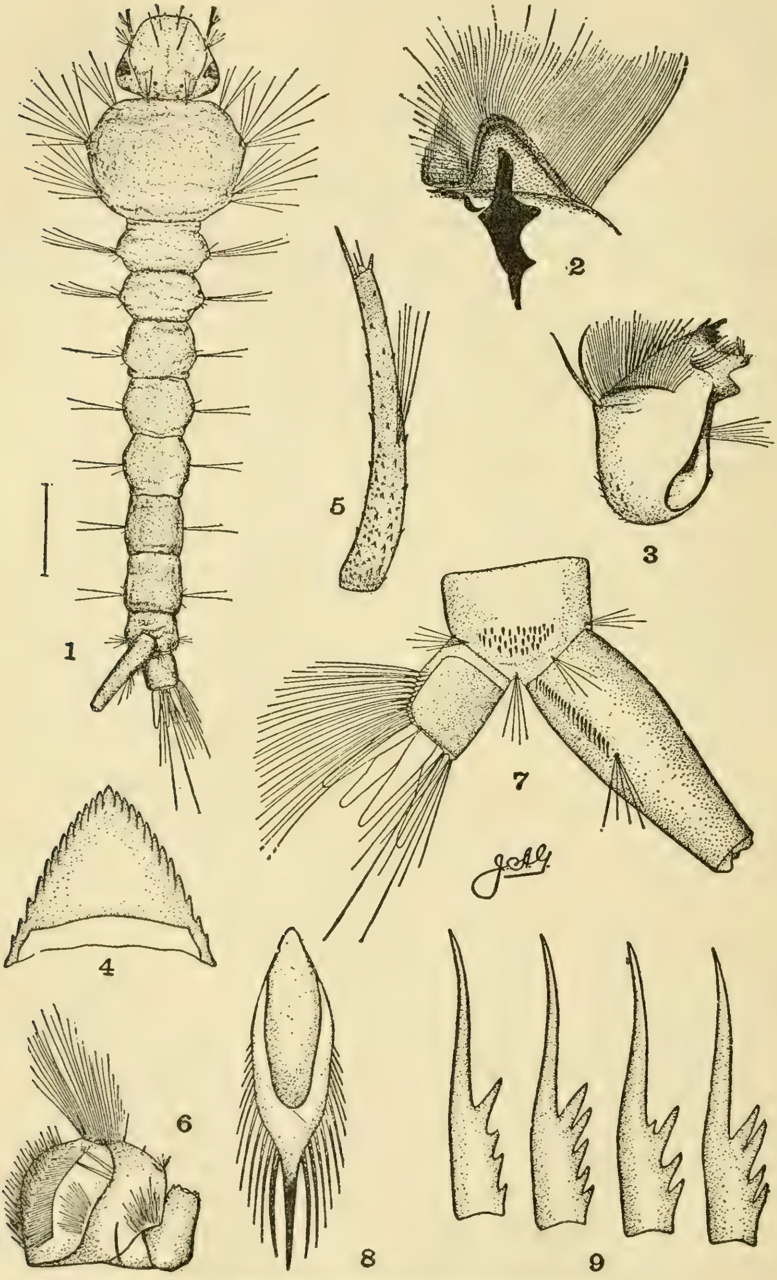


FIG. LVI. Larva of scaly-winged mosquito. *Aëdes grossbecki* D. & K. (After John B. Smith.) 1, larva; 2, mouth brush; 3, mandible; 4, mentum; 5, antenna; 6, maxilla; 7, terminal segments with siphon; 8, a single scale of eighth segment; 9, siphonal spines showing variation (all much enlarged).

HABITS OF THE EARLY STAGES

Full grown larvae were found April, 1903, near Paterson, with *canadensis.* The larvae were recognized as distinct, but were not bred. April 25, four well grown larvae from swampy woods near New Brunswick also failed to develop. May 2, another lot of mixed larvae was brought in, mostly *canadensis.* Pupation began May 3, and a male *grossbecki* emerged May 8, though possibly not from the first pupa. Additional collections were made May 16, mostly pupae and mostly *canadensis;* but in two days fourteen specimens, nearly equally divided as to sex, were bred out. Though this territory was collected over many times later in the season and several other species were found, no further trace of *grossbecki* appeared. It is probable, therefore, that only one brood occurs, and that very early in the season. Nothing is known of the egg laying habits nor of the method of hibernation, but from their early date of appearance and their constant association with *canadensis,* it is probable that the eggs winter like and with those of its associate.

Anopheles barberi Coquillet
The Tree-Hole Anopheles

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States. It is recorded from Plummer's Island, Maryland, August 17, 1905 (H. S. Barber) ; Cabin John, Maryland, October, 1908 (F. Knab) ; Bluemont, Virginia, July 29, 1904 (F. C. Pratt) ; Woodstock, Virginia, August 9, 1904 (F. C. Pratt) ; Tyron, North Carolina (H. G. Dyar) ; Columbia, South Carolina, August 1, 1906 (A. C. Moore) ; St. Louis, Missouri, August, 1904 (A. Busck) ; Agricultural College, Mississippi, October 15, 1905 (G. W. Herrick) ; Scott, Arkansas, October 2, 1908 (J. K. Thibault, Jr.). Reported also from New Jersey (Smith).

Trap records from 1932 to 1941 inclusive show thirteen catches of this mosquito in New Jersey.

Wings without spots. Thorax bluish black with brownish sides. Abdomen brown.]

DESCRIPTION

Howard, Dyar, and Knab (14) give the following description:

"*Female.* Proboscis moderately long and slender, straight, uniform;

labellae long, lanceolate, dull luteous, with small outstanding black setae; vestiture appressed, bronzy brown. Palpi nearly as long as the proboscis, uniform; vestiture brown with a blue reflection; setae rather long, especially at tip. Antennae filiform, the joints subequal rugose, blackish, with long pile; hairs of whorls sparse, black, short; tori subspherical, with a cup-shaped apical excavation, small, blackish. Clypeus small, rounded elliptical, dark brown, nude. Eyes narrowly separated, black. Occiput with a median groove, brown, clothed with erect forked scales, dense and pale brownish yellow posteriorly, more sparse and white anteriorly, a tuft of fine white hairs projecting forward between the eyes; a row of black setae among margins of eyes.

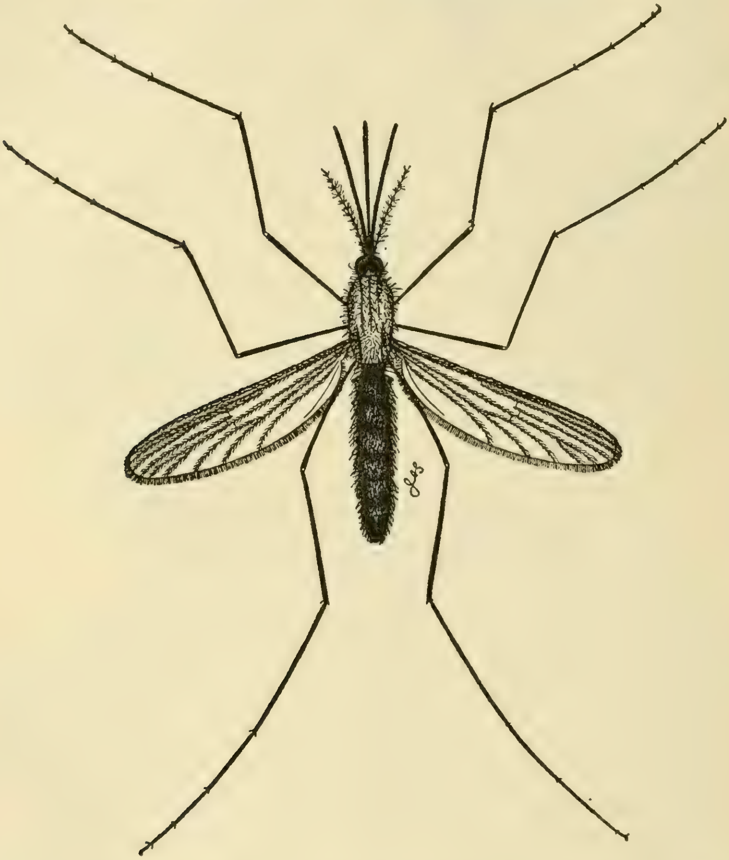


Fig. lvii. Adult of tree-hole Anopheles. *Anopheles barberi* Coq. (After John B. Smith.)

"Prothoracic lobes lateral, small but prominent, bearing coarse brown bristles. Mesonotum short, rounded, convex, dull brown, gray

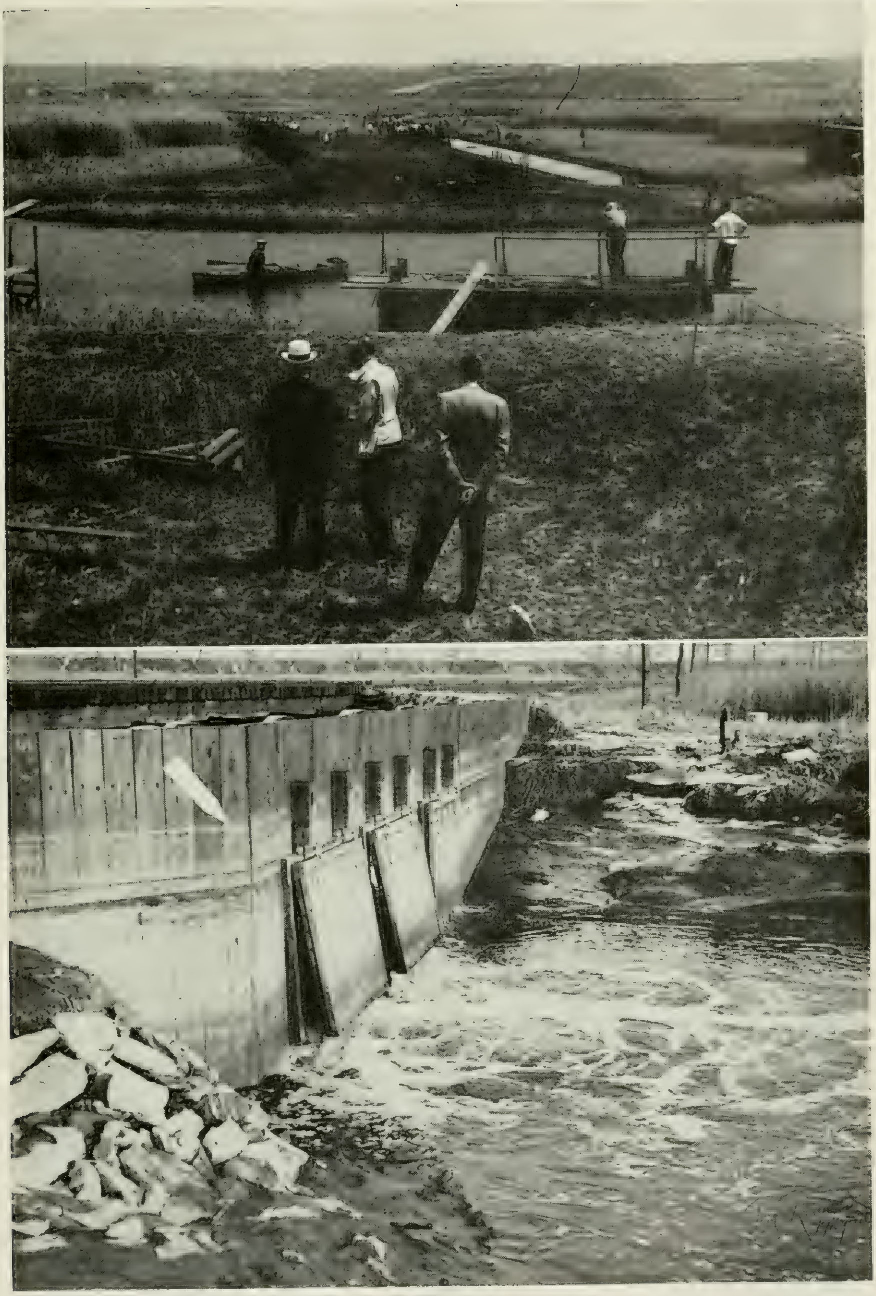


PLATE IX. TOP. Dike under construction on a salt marsh. A tide gate will be built across stream in foreground. BOTTOM. A large tide gate controlling drainage from a 1,200-acre salt marsh. Each tide gate opening measures three and one-half by six feet. Supporting piles, in this case forty feet long, are driven to solid substrata. The tide gate is here shown at low tide; the arrow indicates normal high tide level.

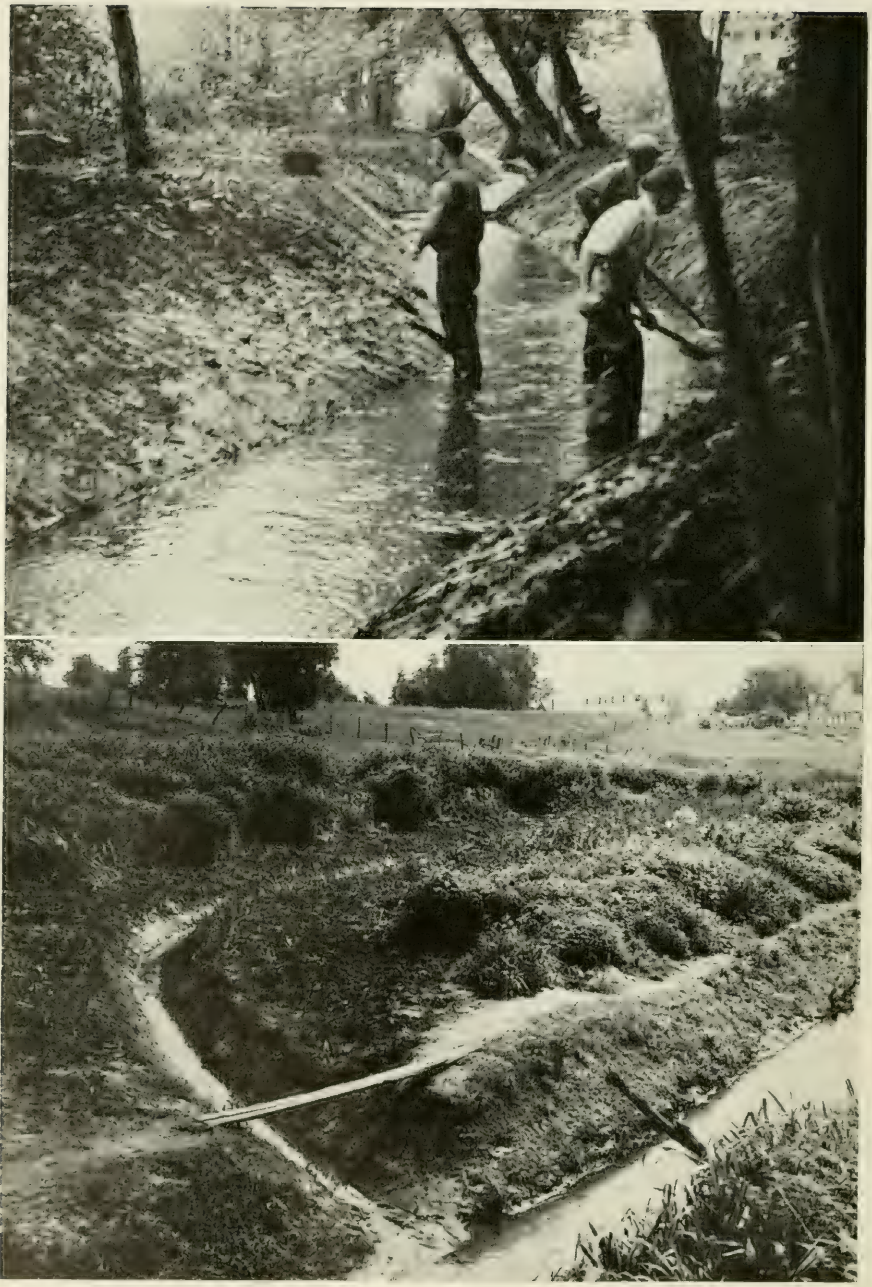


PLATE X. TOP. Upland ditches are usually dug with sloped banks. BOTTOM. Here the lateral ditch feeding the main ditch follows the natural contour of the land.

pruinose on the disk, the margins almost silvery pruinose, two narrow dark impressed bare longitudinal stripes reaching to antescutellar space; vestiture of rather sparse yellowish short hairs on the disk, scattered long and coarse blackish ones toward the sides and in a denser series over the roots of wings; antescutellar space strongly depressed. Scutellum collar-like, luteous brown, with a marginal row of long black bristles. Postnotum elliptical, prominent, brown, nude. Pleurae luteous brown with whitish reflections, coxae yellowish, with a few short hairs, the anterior coxae with a row of long yellow brown bristles.

"Abdomen subcylindrical, somewhat depressed, truncate at tip, brown, the segments with black apical margins; dorsal vestiture of rather numerous and coarse brown bristles, longer ones at the sides.

"Wings moderate, hyaline; petiole of second marginal cell one-third as long as the cell, that of second posterior cell about as long as its cell; basal cross-vein distant about its own length from anterior cross-vein; outstanding scales of veins narrowly lanceolate to almost linear, evenly distributed, uniformly brownish black, those on the costa with a blue and bronzy reflection. Halteres with pale stems and black knobs.

"Legs long and slender; vestiture brownish black with a blue and bronzy reflection. Claw formula, 0.0–0.0–0.0.

"Length: Body about 3 mm.; wing 3.5 mm.

"*Male.* Palpi slightly longer than the proboscis, the last two joints swollen, forming an elongate club, with a few coarse black bristles; scale vestiture bronzy black. Antennae plumose; last two joints long and slender, rugose, black, pilose, the others shorter, whitish, with black basal rings; hairs of whorls long, dense, brown with yellow silky luster. Coloration as in the female. Abdomen elongate, somewhat depressed, broadened toward tip, black; lateral ciliation long and rather dense, brown. Wings narrower than in the female, the stems of the fork-cells longer, the vestiture more sparse. Claw formula, 3.0–0.0–0.0.

"Length: Body about 3.5 mm.; wing 3.5 mm.

"Genitalia: Side-pieces scarcely longer than wide, rounded, a stout seta on inner margin beyond the middle; at base two long spines with contiguous bases, a tuft of long fine hairs from a conical base. Clasp-filament slightly longer than the side-pieces and slightly enlarged at base and apex, with a short and stout articulated terminal spine. Unci columnar, short, with a rounded tip.

"*Larva, Stage IV.* Head rounded, elongated, longer than wide, tapering before, frontal portion before insertion of antennae broadly and somewhat flatly arcuate; hairs all very small, simple. Antennae subcylindrical, short, very slightly tapered, smooth, a single hair at middle; three long, equal, smooth, articulated terminal processes. Eyes inconspicuous. Mental plate small, with a median tooth and five on each side, perpendicular and rounded, the first small, the rest subequal and rather regularly spaced. Mandible elongate quadrangular, slightly convex without; a minute serration on dorsal aspect; two pairs of flat appendages near tip, basal pair ciliate, distal pair bent and with long brush-shaped tips, a pair similar but with smaller appendages just before collar; an outer row of cilia; terminal dentition of seven very large teeth, the third produced, fourth to seventh progressively shorter; a square process of fine dentition, four small retracted teeth within; two filaments above, two within; a quadrate process at end of dentition, a slender one at base; a row of setae outwardly, the inner ones longest. Maxilla rounded rectangular, palpus attached perpendicularly by a pseudo-articulation; numerous hairs and divided filaments on inner aspect; palpus angled at base, short, not longer than the maxilla, a row of short spines on inner aspect, four terminal digits and two small hair tufts. Thorax rounded quadrate, about as long as wide; hairs short, consisting of feathered hairs and a few short simple ones, mesothorax sparsely haired. Abdomen moderate, anterior segments short; long, feathered lateral hairs, double on first two segments, single on third to sixth; a dorsal series of four pairs of fan-shaped tufts on third to sixth segments. Air-tube sessile, subquadrate, roundedly angled posteriorly. Lateral plates of eighth segment posteriorly with a series of long spines without any shorter ones between. Anal segment about as long as wide, with a dorsal plate finely spined behind; dorsal brush of two tufts on each side; ventral brush well developed, of long branched tufts. Anal gills moderate, about as long as the segment, slightly tapered, blunt pointed.

"*Egg.* Short fusiform, strongly tapered toward both ends, black, the surface finely granulate; float consisting of a thin membrane which entirely covers the dorsal surface (in normal position of egg upon water) and projects as a narrow rim along the entire margin, this rim very narrow and crenulate at the ends, broader at the sides, and with a series of numerous impressed transverse lines.

"The eggs were obtained from captured females; they are laid separately upon the surface of the water. The larvae are found only in water in tree holes, in company with larvae of *Aëdes triseriatus* and *Orthopodomyia signifera* and also with *Megarhinus septentrionalis.* The larvae probably feed normally upon small organisms, but have been observed to devour other mosquito larvae with which they were associated. Dr. Dyar obtained small larvae late in the fall, which failed to mature before winter. It is possible that the larvae hibernate, but the hibernation may be normally as adult. This species occurs, with other mosquitoes breeding in tree holes, in forested regions, often when the country is so dry that no other mosquitoes are found."

Culex apicalis Adams
The Little Black Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Temperate to subtropical America. Trapped 3,394 females in New Jersey.]

Small, black mosquito, long, unbanded legs, beak, and unspotted wings. Abdomen narrowly banded with white at apex of segments. This character occurs only in one other of our species, *Psorophora discolor*, and that has spotted wings.

DESCRIPTION OF THE ADULT

One of smallest species of genus *Culex*, very delicate looking; 4.5–7 mm. (.18–.20 inch) long, exclusive of beak, which is 2 mm. long. Head dark brown with scattered whitish scales; proboscis brown, darker toward apex, without marks or rings. Palpi in female brown, shape and position of terminal joint as in *C. pipiens*, except third joint swollen toward tip. In male palpi blackish, basal joint almost reaching tip of proboscis, two terminal ones short, apical slightly shorter than central. Slender, not dilated, precisely as in *Theobaldia melanurus*, figure of which answers perfectly for *apicalis*. Antennae of both sexes brown, plumes of male paler.

Thorax evenly brown without spiny clothing, sides fringed with long, black, curved hairs. Pleura brown with patches of grayish white scales. Femora and tibiae very dark brown, their apices with white spot and under sides wholly creamy white. Tarsi all black without rings or bands. Claws in both sexes agree with those of *C. pipiens*, being equal and simple in female and in posterior tarsi of male, while those of middle and anterior pairs of male unequal in length with single tooth to each claw.

Abdomen blackish brown, with narrow apical bands of white, which become wide at sides, until, beneath wholly white or grayish white.

HABITS OF THE ADULT

It is not definitely known how the insect hibernates, though the indication is that it does so in the egg stage. It is certain that none of the collections of hibernating adults thus far made has produced even a single example of this species.

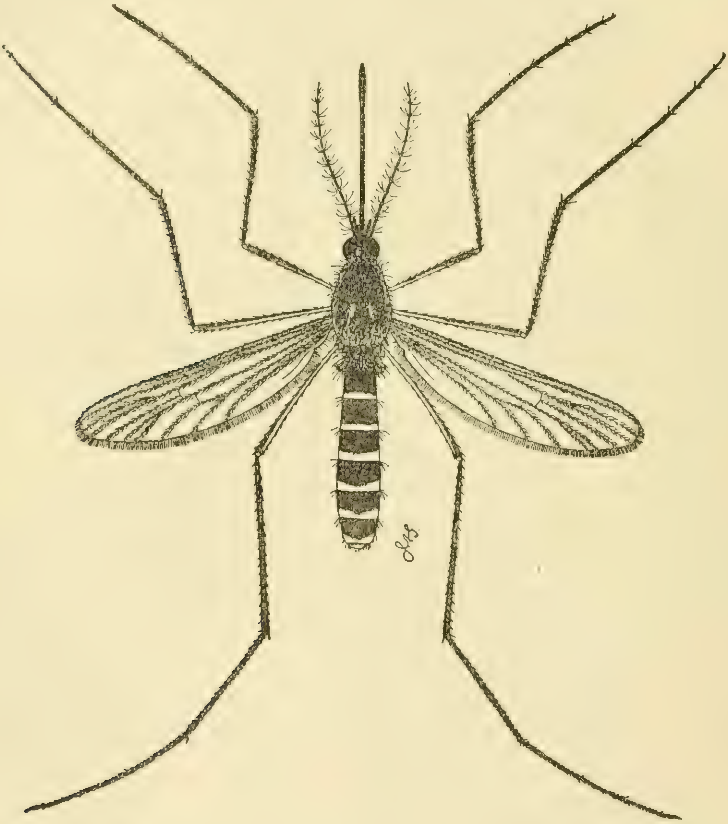


Fig. lviii. Adult of little black mosquito. *Culex apicalis* Adams. (After John B. Smith.)

Among the house collections *apicalis* occurs rarely. In reality, there were thirteen examples out of 318 that seemed referable to this species in the 1902 collection. The collections made in 1903 show an even smaller percentage in a much greater number of examples, all taken late in the season. There is some doubt also about the egg laying habits of the insect, but it seems certain that it makes small boats which probably disintegrate rapidly, allowing the individual eggs to sink to the bottom.

C. apicalis is not a traveler, and seems very local, even where it occurs in considerable numbers.

[According to Howard, Dyar, and Knab (14), Knab found that the eggs are laid in tiny rafts much like *pipiens.* Of two rafts studied one contained 138 and the other 105 individual eggs.]

DESCRIPTION OF THE LARVA

When full grown, 6–7 mm. (.24–.28 inch) long to tip of ninth segment. Slenderly built, whitish or dirty yellowish, sometimes pale green, from color of food eaten. Head very large in proportion to rest of body, subquadrate, about one and one-half times as broad as long. Pale, creamy white, totally immaculate. On anterior part of vertex four hair tufts, each with two long hairs, large tuft of six or seven hairs at base of each antenna. Eyes comparatively small, occupy widest part of head. Antennae large, white, with apical third and base black; broad two-thirds from base, then, curving and becoming abruptly very narrow, large tuft of long hairs on offset thus formed. Surface covered with hair-like spines, apex has three long bristles, very short one and little joint. Rotary mouth brushes, composed of simple hairs, bright orange in color. Mandible triangular, without usual row of long spines on margin between apex and two large curved spines. Maxillary palpus pale, with long white hairs at apex; basal joint extremely small with rather large teeth at its tip. Mentum, broadly pentagonal, has six to eight teeth on each side of apical one, but sometimes teeth extend farther toward base, cutting off lateral angles and giving more triangular shape.

Thorax, somewhat smaller than head, has acutely angled lateral margins from which issue tufts of fine long hairs. Eight other tufts on anterior margin, central two longest extending forward over head.

Lateral margins of abdominal segments very nearly parallel, with exception of anterior two, which have lateral prominences, giving rise to four hairs each, while remaining segments have but two hairs to lateral tuft. Small hairs at base of each tuft, seventh segment having small tufts only. Eighth segment has large patch of twenty-five to fifty extremely small elongated scales with long apical and lateral fringes. Anal siphon pale yellow, very long and slender, usually half as long as the larva from the base of the siphon to the head, inclusive. Broadest at base, slightly constricted centrally, and with two series of weak spines, from ten to fourteen in each series, extending one-third of its length from base. These spines have from three to four long teeth, apical two or three often crowding toward tip; six to eight fine tufts on ventral side between terminating spine and apex. Ninth segment at least one

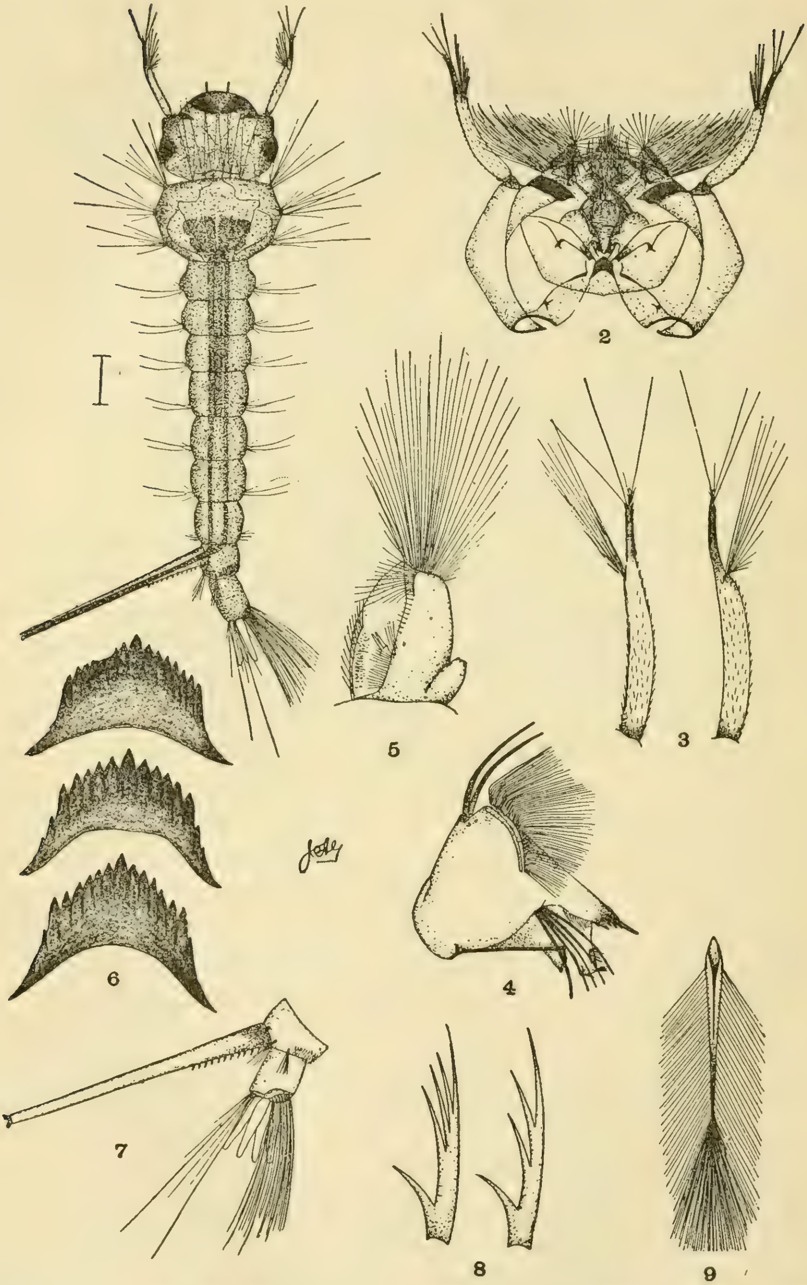


FIG. LIX. Larva of little black mosquito. *Culex apicalis* Adams. (After John B. Smith.) 1, larva; 2, head from beneath; 3, antennae; 4, mandible; 5, palpus; 6, variations in mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, a single scale from eighth segment (all enlarged).

and one-half times as long as broad, with ventral brush composed of but six or seven tufts of long hairs and few short hairs below barred area. Dorsal double tufts have one long hair each and several shorter ones. Anal gills about as long as ninth segment.

HABITS OF THE EARLY STAGES

This is one of the few mosquito larvae that is really recognizable at a glance; the large square head and the very long and very slender anal siphon forming a combination that cannot be mistaken. This is, essentially, a clean water wriggler, though it is occasionally found in stagnant water. At the extreme edge of one of the fish ponds at Lahaway the margin was very shallow, the pine chats from the edge extending under water to some distance, and here specimens could be found in small numbers. Among the grass in a lily pond, also inhabited by fish, examples are also to be found at almost all times. In fact the grassy edge of large ponds is a favorite place for this species, which seems to escape fish better than most other wrigglers. Another favorite breeding place is in the quiet eddies or side pools of even rapid streams where it is usually the only species found. It is frequent in springs and is almost universal in swamp pools formed of spring water. It gets down to the edges of the salt marsh at times and is found in company with *salinarius* in the more permanent pools at the edge of the highland. This is essentially an inhabitant of permanent water bodies and in swamps is the frequent companion of *Anopheles*. But it may be found in pools which dry out completely at times, and even in rain pools and woodland depressions. It is not a universal breeder, however, like *pipiens*, and never occurs in such masses; the larvae are individual in occurrence rather than in swarms.

It is reasonably certain that the eggs winter at the bottom of the pools and ponds where the larvae occur, but whether they will stand a winter drying out or not is a question. The larvae is not an early one. The record is May 12 for single specimens and as late as June 2 a "regular nest of *apicalis* apparently just hatched," is recorded. None of our early collections turn out *apicalis* before the middle of May and it is not until the season is well advanced that they become at all plentiful. They hang on in fall, however, until November, and are among the last of the species to be found outdoors. They were taken in early October in a swampy area along the Passaic, both as full grown larvae and pupae, from each of which forms adults were obtained later in the laboratory.

Whether these late adults taken in October and November mate and oviposit is not known; that they perish soon after they are born is indicated by our failure to find any of them in winter quarters.

Taken as a whole, this can scarcely be counted among the really troublesome mosquitoes, and that is fortunate, because it is one whose breeding areas it would be most difficult to control. No other *Culex* lives in water so shallow as this, and no other is an inhabitant of streams and ponds to the same extent. *Anopheles*, however, does occur with *apicalis* in most of its breeding places and any attempt to control the one would naturally affect the other.

[On the question of hibernation, Howard, Dyar, and Knab (14) say, "Dr. Smith's opinion that *Culex apicalis* hibernates in the egg state seems ill-founded and at variance with what is known of the other mosquitoes which lay their eggs in a mass or raft. The larvae appear later than those of any of the forms known to hibernate as eggs and undoubtedly come from eggs deposited in the spring by hibernated females. Knab has taken hibernated females in March, in the vicinity of Washington. These were among the crevices of stones overhanging a spring in the woods and had undoubtedly passed the winter there. It would seem from Dr. Smith's observations that this species does not seek the shelter of buildings for hibernation and on this account its mode of passing the winter had not been determined."]

Theobaldia morsitans Coquillet
Dyar's Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Northern New York and New England, westward in Canada and southward in elevated areas. It is recorded from Center Harbor, New Hampshire, larvae in an old barrel in swampy spring, May 1902 (H. G. Dyar); Springfield, Massachusetts, May 21, 22, 23, 24, 27, 28, 29, 1903 (F. Knab); Suffield, Connecticut, May 12, 1903 (F. Knab); Tupper Lake, New York, larva in a cold swamp, adult issued August 16, 1905 (H. G. Dyar); Saxeville, Wisconsin, May, 1910 (B. K. Miller); Kaslo, British Columbia, a larva in a cold springy swamp, May 29, 1903 (H. G. Dyar); Culvers Lake, New Jersey, May 29, 1908 (in collection of J. B. Smith). Also recorded from Branford, Connecticut (E. P. Felt).

Trap collections from 1932 to 1941 inclusive show no catches of this species.

Medium sized, or small, dark brown, thorax reddish brown on top and grayish on sides. Abdomen blackish brown with narrow bands of yellowish white. Legs dark brown, narrowly banded with silvery yellowish.]

DESCRIPTION

Howard, Dyar, and Knab (12) give the following description:

"*Female.* Proboscis long, uniform, labellae conically tapered; vestiture black, with a bronzy luster, labellae brownish; setae small, curved, black, those on labellae more prominently outstanding. Palpi short, one-fifth as long as proboscis, clothed with blackish scales, the tips yellowish scaled, with many short, stiff setae. Antennae long, the joints subequal, rugose, pilose, black, second joint slightly enlarged; hairs of whorls rather short, sparse; tori subspherical with a cup-shaped apical excavation, yellowish, brown on inner side. Clypeus rounded triangular, blackish, nude. Occiput dark brown, rather sparsely clothed with coarse, narrow, curved, pale yellow scales, denser towards the sides, margins of eyes and the cheeks white scaled, scales on lower part of sides flat; many very slender, erect, forked black scales, most numerous on the nape and sublaterally; setae along margins of eyes rather short, curved, black.

"Prothoracic lobes elliptical, remote dorsally, with narrow white scales and many black setae. Mesonotum dark brown, reddish brown in two approximated longitudinal bare convex stripes and two others posteriorly at sides of antescutellar space; vestiture of short hair-like bronzy brown scales in two broad stripes at outer sides of bare submedian stripes and on posterior half of disk, coarser pale yellowish ones in a median stripe; on sides of disk anteriorly, about lateral depression, about the antescutellar space, and along the posterior bare stripes. Scutellum trilobate, brown, clothed with narrow, curved, shining pale yellow scales, each lobe with a large group of brown bristles. Postnotum elliptical, prominent, brown pruinose, nude. Pleurae and coxae luteous, with darker spots and patches of lanceolate whitish scales and rows of pale bristles.

"Abdomen subcylindrical, depressed, truncate at tip; dorsal vestiture of blackish brown shining scales, bases of segments with pale yellowish narrow bands; first segment with a small patch of white scales in the middle and with many pale hairs; venter sparsely clothed with pale dirty yellowish scales, and numerous dark hairs.

"Wings ample, hyaline; petiole of second marginal cell much shorter than its cell, that of second posterior cell also shorter; basal cross-vein distant almost its own length from anterior cross-vein; scales brown, those on costa black, the outstanding ones numerous, broadly linear, densest apically; a slight tufting at base of third vein. Halteres pale, with blackish knobs.

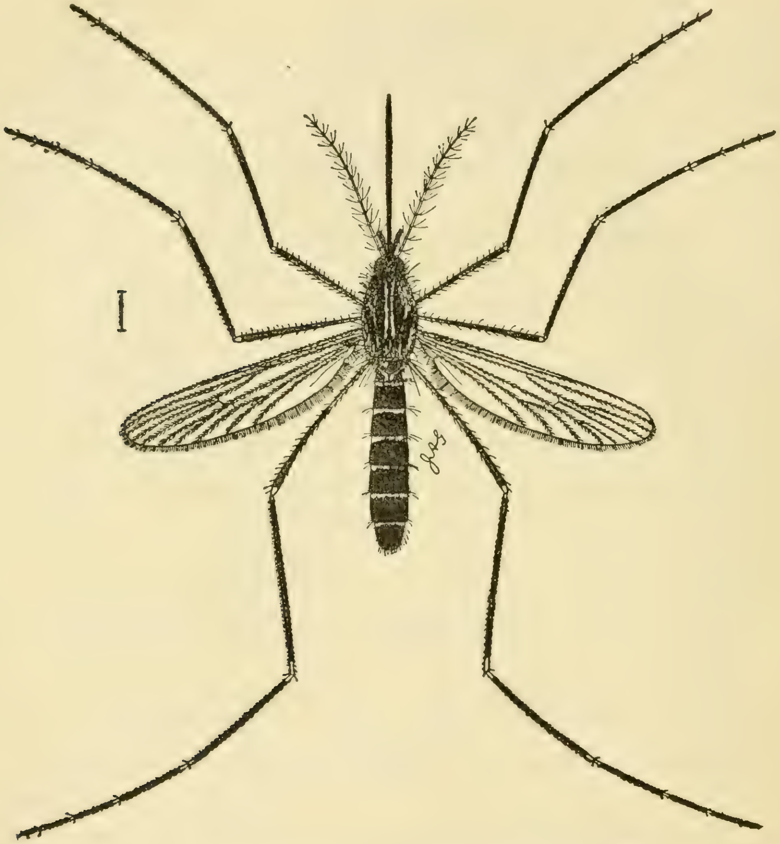


Fig. lx. Adult of Dyar's mosquito. *Theobaldia morsitans* Coq. (After John B. Smith.)

"Legs long and slender; vestiture blackish; femora whitish beneath to near apices, broadly so at base, knees yellowish white; tibiae black, with yellowish apices, a narrow ill defined pale line ventrally on median pair; tarsi blackish with bluish and bronzy reflections, the joints with minute basal yellowish white rings or spots, last joint of hind tarsi entirely black. Claw formula, 0.0–0.0–0.0.

"Length: Body about 5 mm.; wing 5.5 mm.

"*Male.* Proboscis straight, uniform. Palpi exceeding the proboscis by more than the length of the last joint, slender, blunt at tips; last two joints and end of long joint thickened and bearing many long black and yellowish hairs; vestiture of brownish scales, a patch of yellowish ones at bases of two last joints, a narrow pale ring at basal third of long joint and a long patch dorsally at its apical third. Antennae plumose; last two joints long and slender, rugose, pilose, black, the others short, slender, whitish, with thick black rings at insertions of the hair whorls; hairs long, dense, black. Coloration similar to the female. Legs with a strong bronzy luster, the tarsal rings obsolete. Wings narrower than in the female, the stems of the fork-cell longer, vestiture sparse. Abdomen elongate, depressed; dorsal pale bands broader than in the female; lateral ciliation long and abundant, brownish. Claw formula, 2.1–2.1–0.0.

"Length: Body about 5.5 mm.; wing 4.5 mm.

"Genitalia: Side-pieces elongate, conical, uniform, without lobes; clasp-filament long, uniform, slightly enlarged at base with a small inserted terminal claw; a rounded lobe within base of side-piece bearing a row of stiff setae. Harpes simple, curved, with revolute margins. Harpagones small, curved, simple. Unci forming a slender, elongated cone reaching beyond middle of harpes. Basal lobes short, rounded, bearing, several setae.

"*Larva, Stage IV.* Head square, transverse, a notch at insertions of antennae, the front margin rounded, flat before; eyes large, transverse. Antennae large, cylindrical, tapered without, densely spined; a large tuft at outer third; apical setae very long, two some distance before tip, a long and a short one and a small digit at tip. Upper pair of dorsal head-hairs quadruples, lower pair double; ante-antennal tuft multiple. Mental plate triangular, a central tooth and nine on each side, becoming progressively larger and more remote toward base, except the last two which are very small and distantly spaced. Mandible quadrangular, elongate; two filaments before the tip arising in a thorn-shaped notch with two small hairs; an outer row of cilia from a collar; a row of little tufts along the outer edge arising from slight transverse ridges; dentition of four teeth on a process, the first the largest, with two sharp teeth without, a small tooth at base, a slender filament and a long row of feathered hairs within; a long conical tooth below; further below a furcate process bearing tufts of hair; basal angle long and slender; a long row of hairs toward the base. Maxilla conical, divided by a suture; inner half hairy toward base, and a group of stiff hairs at middle; a tuft of very long hairs at apex running along the suture, outer half with hair toward the suture, the two filaments small. Palpus small, with four terminal digits, the two next the maxilla longest. Thorax rounded, wider than long; hairs abundant, very long, the anterior prothoracic tufts exceeding the head. Anterior abdominal segment short, posterior ones elongated; lateral tufts of first two segments multiple, a single long hair on third to sixth, not shorter posteriorly, very short on seventh segment. Thracheal tubes narrow, linear, angled in the eighth segment. Air-tube long, slender, straight, scarcely tapered, about six times as long as wide; pecten of few teeth on basal fourth, the single teeth a short spine with very broad base and four long basal spines; no hairs on the tube. Lateral comb of eighth segment of numerous scales in a very large triangular patch, the single scales with broadly expanded apex fringed with short spines. Anal segment nearly twice as long as wide, ringed by the plate; dorsal hairs a tuft and long hair on each side; a single lateral hair; ventral brush well developed, preceded by a row of short tufts along the ventral line to the base and arising from little holes in the chitin. Anal gills slender, about as long as the segment, pointed.

"The larvae occur in cold springs or bogs early in the season, always in small numbers. There is but one annual generation, the larvae hatching with the melting of the snow and maturing early. The egg is unknown, but probably is deposited singly, and the late summer and all winter passed in this stage. The adult is rare, only single specimens being taken, so that its habits are unknown."

Theobaldia melanurus Coquillet

The Black-Tailed Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from Canada to the Gulf of Mexico. It is rare and local. In New Jersey 1,287 specimens have been trapped.]

Rather small, dark brown, legs and beak unbanded. Wings unspotted, segments of abdomen have merest indications of white bands at base.

DESCRIPTION OF THE ADULT

Could easily be taken for *C. pipiens*, especially if latter were worn so as to render banding obscure; however, smaller and of richer brown color. Body, exclusive of beak, measures 4–5 mm. (.16–.20 inch) long, beak three-fifths length of body; average width across wing about 8 mm., or .32 inch. Large black eyes cover anterior part of head; occiput is covered with white scales. Palpi in female short, four-jointed and set with rather long hair; terminal joint reduced to extremely small circular knob, slightly retracted within third joint. Male palpi

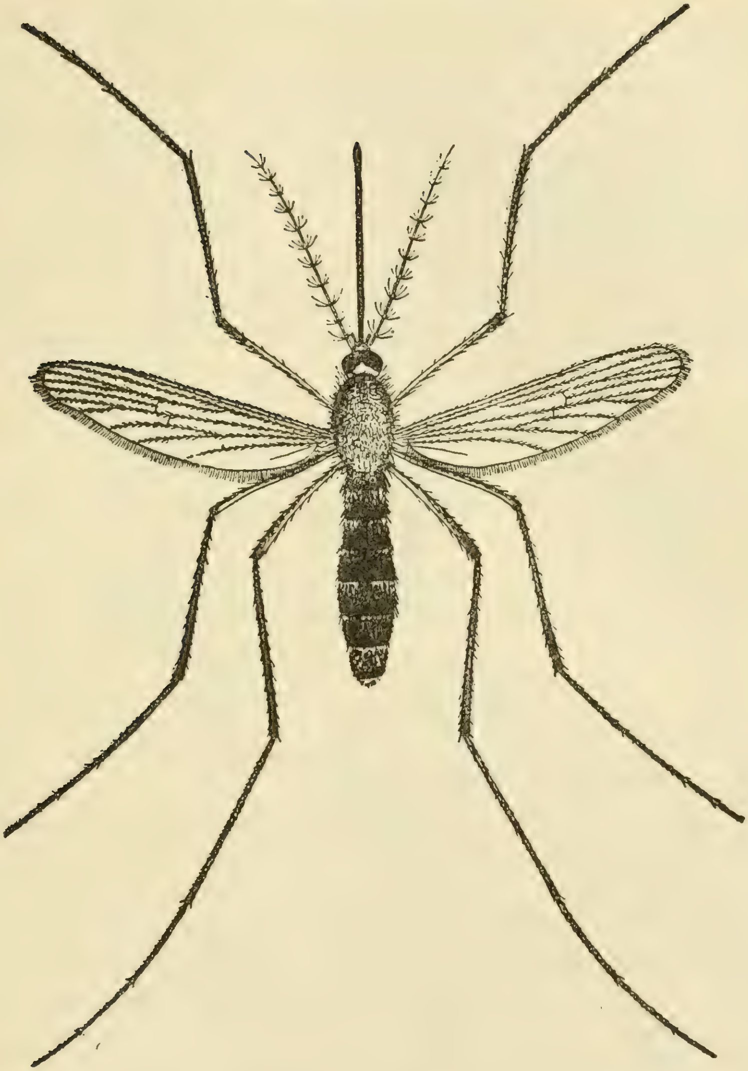


Fig. lxi. Adult of black-tailed mosquito. *Theobaldia melanurus* Coq. (After John B. Smith.)

little longer than beak, not dilated, basal joint with slight angulation just before middle; brown, terminal joint white at base. Fan-like tufts toward tip, though long, not dense. Antennae of male plumose, longer than basal segments of palpus, two terminal joints long and slender, others cup-shaped, with usual circle of long silky hairs. Female antennae slightly longer than beak, joints of uniform lengths, brown, white, at base, set with rather short stiff hair over surface, with circle of long bristles at base of each.

Thorax evenly brown, covered with very short spiny hair. Legs dark brown, with under side of femora yellowish white. In male inner claw of anterior tarsal joint long, with median and basal tooth; outer claw smaller, has only single tooth near base. Claws of middle tarsal joints same, except a little longer and more slender; claws of the hind tarsal joints simple. In female claws are alike on all feet, same as posterior ones of male.

Abdomen dark brown, very narrowly banded with yellow white at base of segments. Sometimes bands obsolete; sometimes, on the more anterior segments, divided in the center by the brown. Beneath color is ashen gray in females, but darker in males.

HABITS OF THE ADULT

Practically nothing is known of the habits of the adult; but it is reasonably certain that the species does not bite, hence cannot be ranked as pestiferous.

In general appearance it resembles an undersized, dark *pipiens* and would not be readily distinguishable from it, if the two flew together.

DESCRIPTION OF THE LARVA

When full grown measures, exclusive of anal siphon, 7–8.5 mm. (.28–.34 inch) long, delicate build; pale yellowish or bronzed grayish. Head yellowish brown; siphon dark brown, black toward tip, rendering it rather conspicuous in contrast with paler color of larva. Head large, almost size of thorax, not quite three-fourths as long as broad, rounded in front and full at sides, with decided offset between vertex and genae for reception of antennae. Vertex immaculate, with two small hair tufts near center; one long hair slightly in advance of each; another tuft is at base of each antenna. Antennae long and slender, narrower beyond tuft, curved inwardly, uniformly grayish brown, with surface covered with long spines. Tuft large, composed of many long hairs and arises from offset at outer fourth; apex with three very long bristle-like hairs, one short bristle and very small terminal joint, all articulated. Eyes reniform, not large, situated on sides where head is widest; sometimes eye divided into two parts, one large anterior body and little one at center, posteriorly. Hairs composing rotary mouth brushes long and silky, not pectinated. Very little variation in mentum, usually two and one-half times as broad as long. From seven to nine large teeth on each side of apex (eight being average), which have tendency to point toward center. Mandible triangular, rounded at corners, dorsal part with three long, curved spines and number of

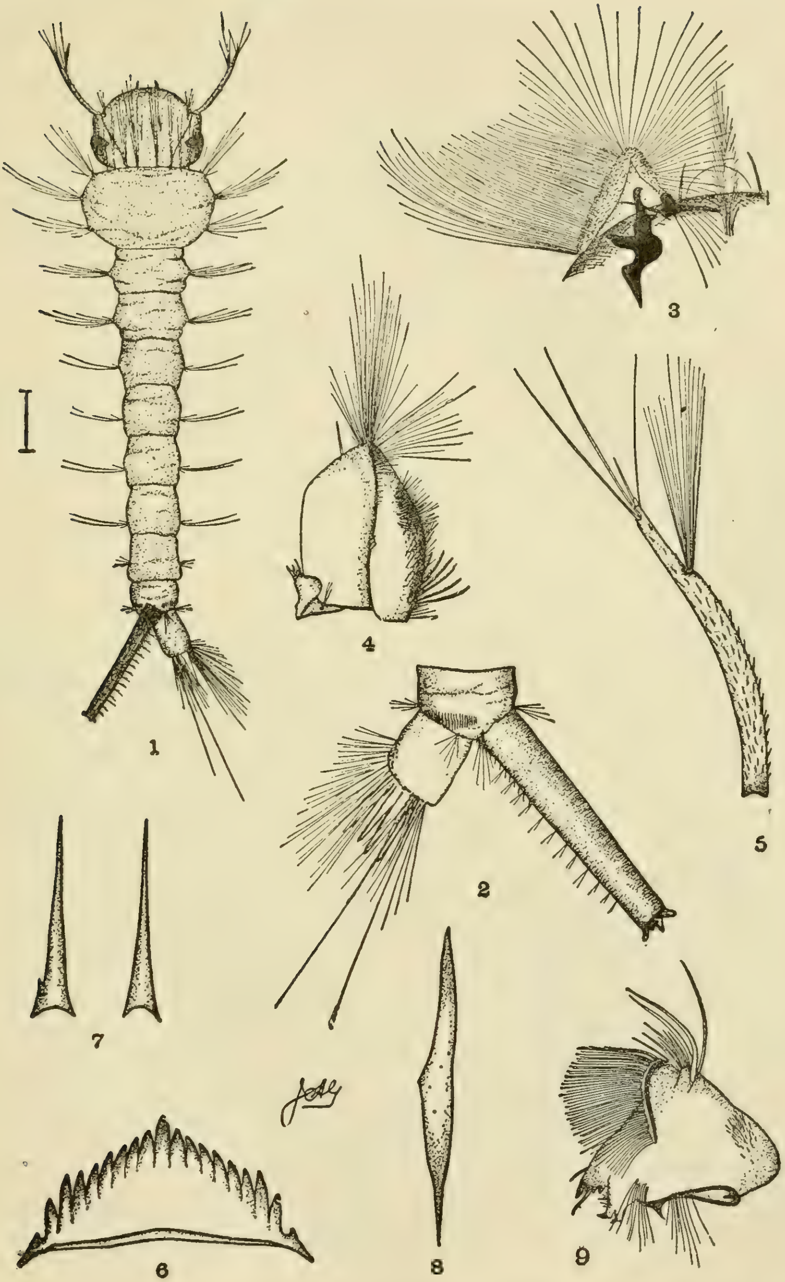


Fig. lxii. Larva of black-tailed mosquito. *Theobaldia melanurus* Coq. (After John B. Smith.) 1, larva; 2, terminal segments with siphon; 3, mouth brushes; 4, maxillary palpus; 5, antenna; 6, mentum; 7, siphonal spines; 8, scale from eighth segment; 9, mandible (all enlarged).

short ones, outer part of base with patch of fine hair-like spines. Maxillary palpus has moderate tuft of long hair on apex and number of pectinated hairs on base. Basal joint very small with four spines at apex.

Thorax angulated slightly, transversely oblong, with numerous hairs arising from tubercles at angles of sides; anterior margin has some very long stout hairs extending beyond head, most central ones being grouped at base, but issuing from separate tubercles; more lateral ones separated at the base, each with one or two hairs.

Abdominal segments from one to seven subquadrate, anterior two with lateral tufts of four or five hairs each, following four with tufts of two hairs; those of the seventh and eighth very much reduced. Scales composing combs of eighth segment greatly elongated from seventeen to twenty-six in number, arranged in single row. Anal siphon five or six times as long as broad, tapering slightly toward apex, dark brown, black tipped, with double row of very small, simple or one-toothed spines, eleven to fifteen in each row. On ventral border row of about thirteen small, fine-haired tufts extending entire length. Ninth segment considerably longer than wide, with ten or twelve tufts on dorsal part of apical margin also short, each with one very long hair. Anal gills as long, or nearly as long, as ninth segment.

HABITS OF THE EARLY STAGES

From time to time a collector had mentioned a "bronze wriggler" which occurred in woodland springs, very late in the season, specimens being taken up to the middle of November; but no attempt was made to breed it until, after a specimen had been sent to Dr. Dyar, who pronounced it *melanurus*, a species originally taken by him in New Hampshire. In the winter of 1902–1903 Mr. Brakeley determined to test his belief that these larvae hibernated in that condition and found that there were several places on his land where they could be found other than the springs, nearly or quite all of which had a greater or smaller supply. The chief point of interest was a stretch of swampy bog land that had been burnt over early in 1902, the fire eating through the moss in places and leaving a mass of irregular holes, varying in size and depth. Some of these were partly closed by vegetation covering in from the edges and making an overhang. The ground was springy and there were numerous springs round the edges, so that the water was always cold and usually clear, but with a flocculent sediment which was readily stirred up.

January 9, 1903, with the thermometer 9° above zero, the entire

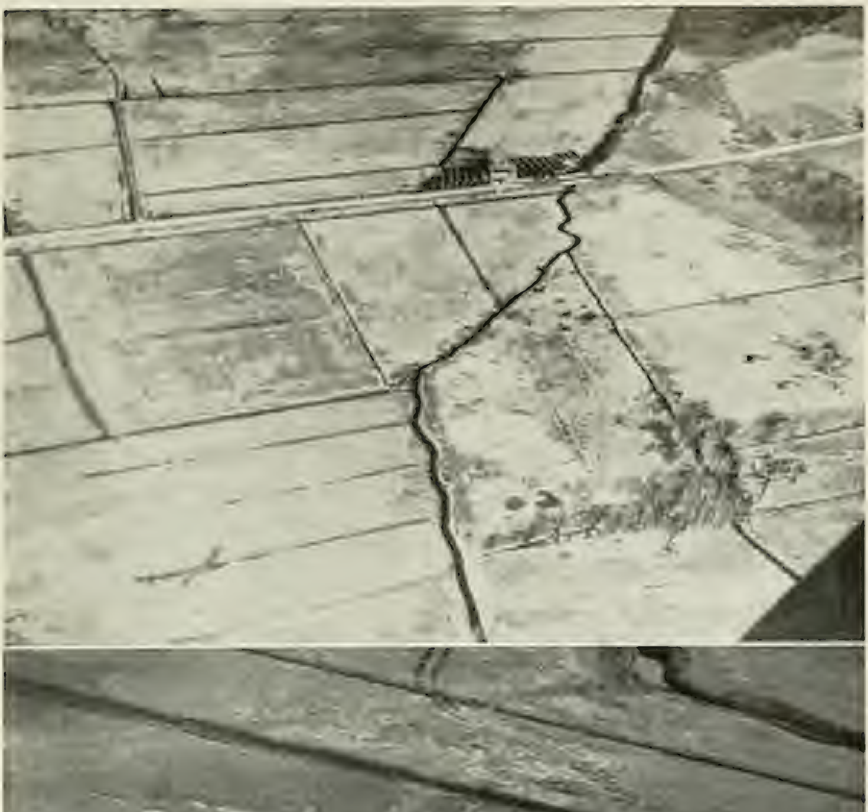


PLATE XI. TOP. Aerial view showing pattern of drainage ditches in level upland meadow. Highway crosses main stream in vicinity of fish hatcheries in middle distance. BOTTOM. Aerial view of salt marsh showing in foreground many water-filled holes in which mosquitoes breed. In background ditching machine is installing parallel ditching system. The ditches are one hundred fifty feet apart.

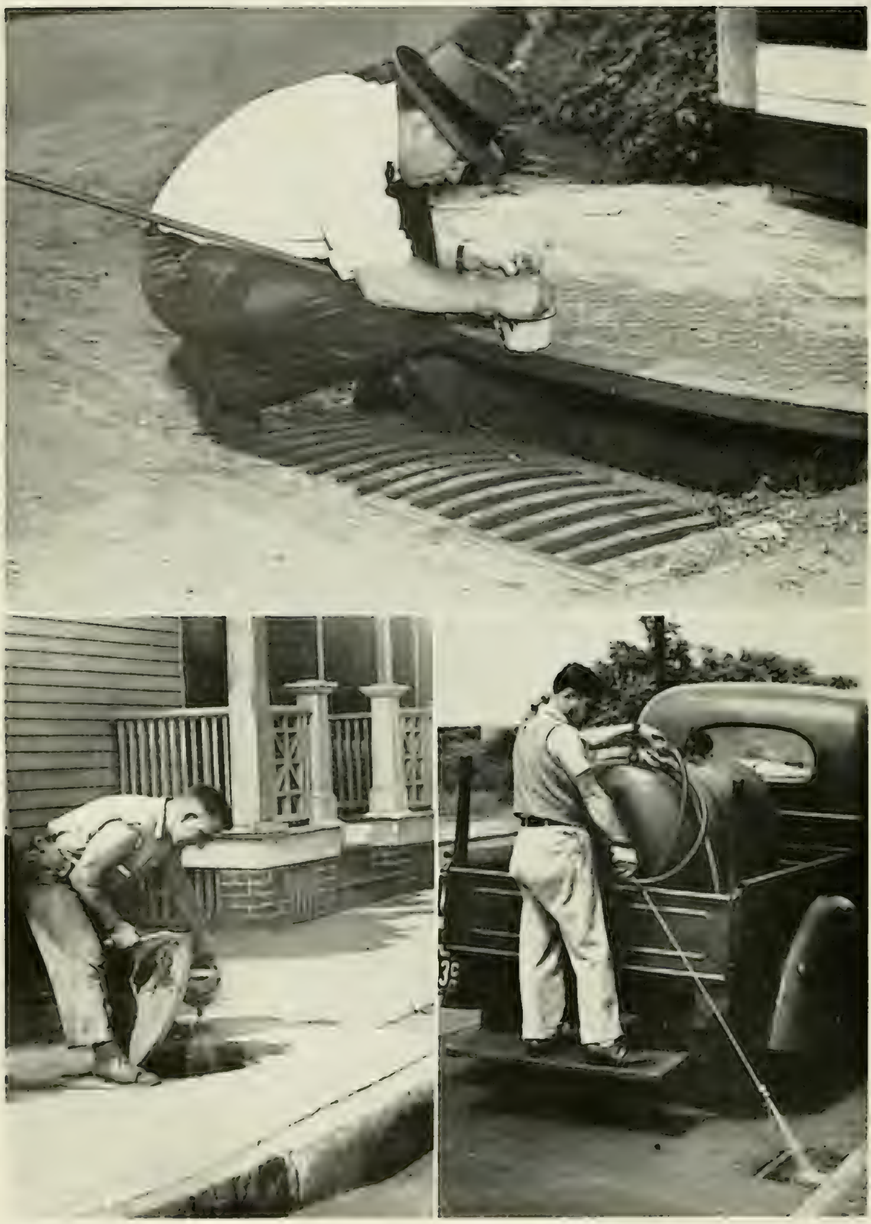


PLATE XII. TOP. In urban areas street drainage catch basins are a source of prolific breeding of house mosquitoes. BOTTOM LEFT. Hand oiling sewer catch basin by using ordinary garden watering can or hand sprayer (not illustrated) practicable in densely populated areas where heavy traffic interferes with the use of power equipment. BOTTOM RIGHT. This power sprayer, designed for treating catch basins and flooded cellars, is equipped with a long hose to permit the operator to work at a distance from the truck. Pressure is developed in oil tank by utilizing a small air compressor driven by the fan belt of the truck motor.

swamp was frozen solid. January 23, I broke the ice on likely pools and made about a dozen dips in as many places. Nothing was found and the inference is that the insects shelter either in the mud or under the overhanging vegetation. January 30, during a mild spell, collections were made in pools from which the ice had just disappeared, and now quite a little series of specimens was obtained, some of them inactive and apparently dead, but all revived when brought indoors. On the thirty-first, I covered another part of the same territory and found specimens everywhere: "Little holes, not over two inches in diameter, full of water, turned out two or three specimens." February 1, collected additional specimens and brought in some of the ice to see whether larvae were frozen in it. I found that there were none and that the specimens probably kept down below actual frost, if possible. February 7, it was noted that there was considerable difference between the larvae, as though two or more stages were represented, and, as a whole, they were more advanced than in December; in the larger specimens a distinct shield-like form of the thorax was now apparent. Collections were made throughout February, and the indoor cultures were under constant observation; but though the larvae seemed to feed continually they did not grow and spent most of the time at the bottom of the jars; they do not need air from above the surface. On February 22, when the ground was snow covered and everything frozen over, holes were made in the ice and active larvae were dipped up from beneath it. The water here was 36°, and in the woodland springs where other specimens were taken it ran 42°. Rain and snow so filled the swamp area that the wrigglers were scattered over so large a territory it was almost impossible to find them. At this time a series of the specimens was sent to me to be developed in the laboratory, and these arrived in good condition. Throughout March collections were made, and during this time it became so dry that it seemed as if all the larvae must have perished; yet after a rain there were as many as ever. They seem able, apparently, to seek out the wettest places and may even survive for a time in soft mud. April 2 and 3 another lot of over 100 larvae was collected for shipment to me, and up to that time there had been no pupa seen. The first specimen in the culture material pupated April 4, and as I obtained the first pupa just a day earlier, this may be considered the beginning of the pupation period. The pupa is small in proportion to the size of the larva and the period of this stage is from six to ten days. The last larvae were collected May 5, and in nature only one pupa was taken, an accidental one mingled with *canadensis*.

This record of collections made is an interesting one and proves positively that the larva of *Theobaldia melanurus* lives through the winter in the half grown condition. It is essentially a clean water wriggler and requires a sheltered locality, like woodland, or an overgrown swamp area, to develop. An area that freezes solid would probably prove fatal, but in spring water the temperature rarely gets much below 40°, even in the coldest weather, and when there is an ice covering in the swamp there are the recesses under the edges and the deep, soft mud to serve as retreats. I have no record of the recurrence of this larva in the springs before October, and none of the summer collections contained specimens. Nor have I seen any very small larvae or eggs.

A characteristic feature of the species is its remarkably slow growth in spring and the long delay in pupation. The larvae are half grown, or more, before *canadensis*, or *aurifer*, are born, yet the latter become adult as soon, or sooner. They are slow in their movements and seem to take life easy, "like a group of dreamy philosophers," as one collector puts it. They are bottom-feeders of necessity, since the water in which they live has only a small supply of organic life, but in the leaves at the bottom of the springs and in the mud of the swamp pools their food is found. So they have well developed trachea in the anal gills and are not dependent upon atmospheric air for their supply of oxygen. This peculiarity is also essential, as their swamp breeding places become completely ice covered.

As to the egg laying habits, nothing is known to me. They are probably laid on the surface and may, or may not, sink to the bottom before hatching.

Orthopodomyia signifera Coquillet

The White-Lined Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from Massachusetts to Texas. Trapped sixty-one females in New Jersey.]

Medium sized, black, with hind tarsi broadly white-banded at each end of joints, last one entirely white; bands of front and middle tarsi very narrow, if present at all, confined to apices of joints, except first one on the middle tarsi. The beak unbanded. Thorax black, marked with narrow white lines. Wings grayish, with distinct white spot at cross-vein; abdomen dark brown, with white lateral marks which tend to cross dorsal surface.

DESCRIPTION OF THE ADULT

Moderate build, measuring 5–5.5 mm. (.20–.22 inch) long, excluding proboscis, which not quite half length of body. Head velvety black with some white scales scattered on central part; clearly defined white border to eyes. Proboscis narrow at base, becoming dilated toward tip; black, with white scales scattered at sides, forming black median line. Palpi in female little over one-third the length of proboscis, three-jointed, basal two joints long and slender, black with few white scales, terminal one very small and wholly white. In male palpi slender, as long as proboscis, three-jointed, basal joint long, terminal one very small; black with some white scales, base of second joint and all of third white; few long bristles on last two joints. Female antennae black with scattered white scales; in male black with silky brown plumes.

Thorax velvety black with fine white hairs over surface and long lateral black ones; two bluish white, narrow dorsal lines on anterior two-thirds; two similar arcuate lateral ones extending entire length of thorax; two broken ones on posterior half which extend forward between lateral and central ones. Pleura blackish with few white scales collected into small patches. Femora and tibiae black with white scales sparingly scattered over surface, their apices and base of tibiae in posterior legs white, bases of femora yellowish, especially on under side. Anterior and middle tarsi black, usually without rings, though extreme apices of joints and base of first joints of middle tarsi pale, often distinctly yellowish. Posterior tarsi broadly banded with pure white at both ends of joints, last one wholly white. Claws of male anterior and middle tarsal joints unequal, larger with long blunt tooth one-third from base, smaller with extremely small acute tooth near base; posterior claws equal and simple. Female claws equal and simple on all feet. Wing veins clothed with brown and white scales, giving wing grayish appearance. On radius and media, at connection with cross-vein, white scales only, which together form distinct white spot; scales on basal half of anal vein also white.

Abdomen brownish black with considerable variation in banding. Always large white spot, sometimes divided transversely in two on basal segment, confined to dorsal surface. Following three segments have narrow, ill-defined basal bands, often entirely obsolete; apical

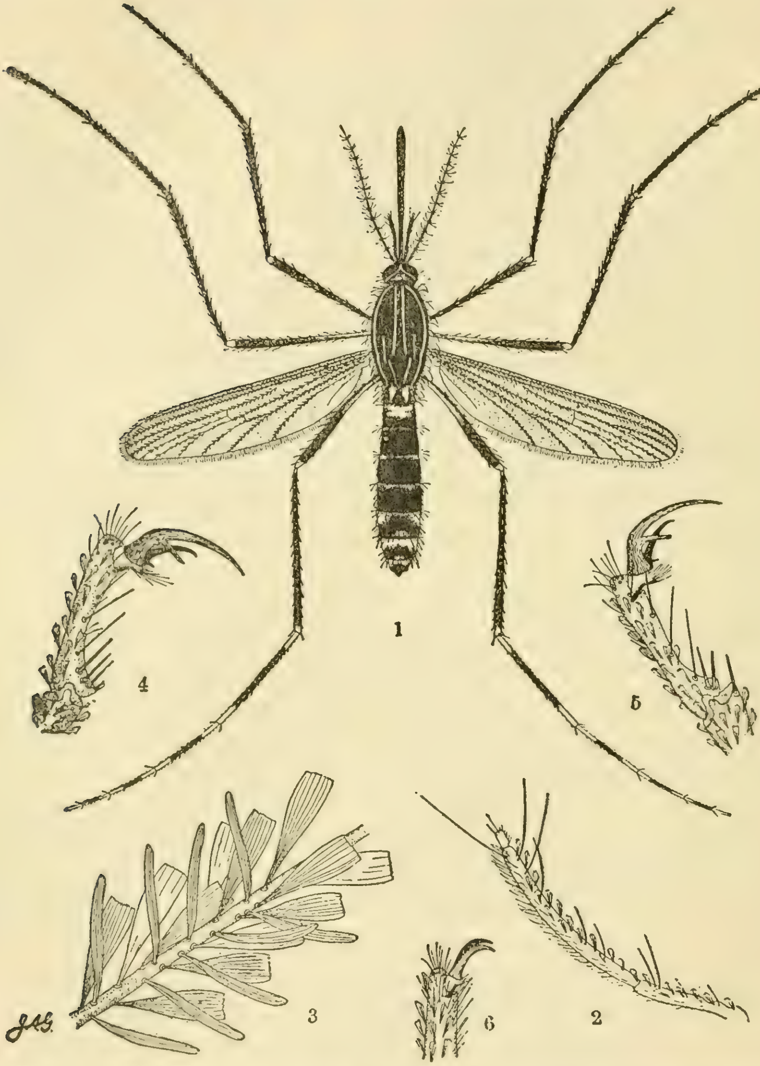


Fig. lxiii. Adult of white-lined mosquito. *Orthopodomyia signifera* Coq. (After John B. Smith.) 1, female adult; 2, palpus; 3, part of wing vein showing scales; 4, anterior, 5, middle and 6, posterior claws of male (all much enlarged).

three segments have wider bands which become broad laterally and join side markings. Small patches of white scales sometimes near apical margins of penultimate and antepenultimate segments. Venter brown, with diffused whitish bands at base of segments, sides more clearly marked, with white markings joining bands of dorsum.

HABITS OF THE ADULT

Practically nothing is known of the habits of the adult. It has never been taken, indoors or out, by any of the collectors, although they have collected in the localities where the larvae were found. So far we have only bred adults out of larvae coming from Delair and Chester. The larva only has been taken at Lahaway. According to Matheson (18), it can be found resting on trees in the holes of which it breeds. It has been taken frequently in trap collections.

The mosquito is a very pretty one when examined under a magnifying glass, and by its narrow white lines on the thorax recalls the yellow fever mosquito; indeed, it was at first placed in the same genus —*Aëdes.* There is nothing about it to indicate that it cannot bite; but so long as it remains so rare the question is hardly to be considered important.

DESCRIPTION OF THE LARVA

Stout, chunky; when full grown 7–8 mm. (.28–.32 inch) in length, exclusive of anal siphon. Grayish black with thorax somewhat lighter, except head, siphon, and dorsal plating. Head purplish black, long as broad, has straight sides, rounded in front and at base. Six equally spaced hair tufts of five or six hairs each in transverse row on anterior part of vertex, four central ones slightly to rear and lateral two very close to base of antennae. Antennae short, dilated at basal third, taper toward tip; apex has two long spines, two smaller ones and little articulated peg. Surface destitute of spines or hair, tuft situated on shaft a little over one-fourth from base, consisting of about six feathered hairs. Eyes small, transverse, surrounded by yellowish ring. Rotary mouth brushes orange or yellowish, composed of simple hairs. Mandible normal, maxillary palpus rather broad, square at base, with obtuse apex and large apical tuft; basal joint long and slender. Mentum is almost equilateral triangle with large apical tooth, then five or six small lateral ones, blunt at tips; four very large pointed ones below these. Usually nine teeth on each side of the apex, but occasionally one has ten.

Thorax wider than long, very thick, anterior angles somewhat sharply angulated. Six lateral hair tufts moderate in size, two small tufts near anterior margin.

Abdominal segments oblong or subquadrate, with five or six hairs to each lateral tuft in two anterior segments and very slight tufts in

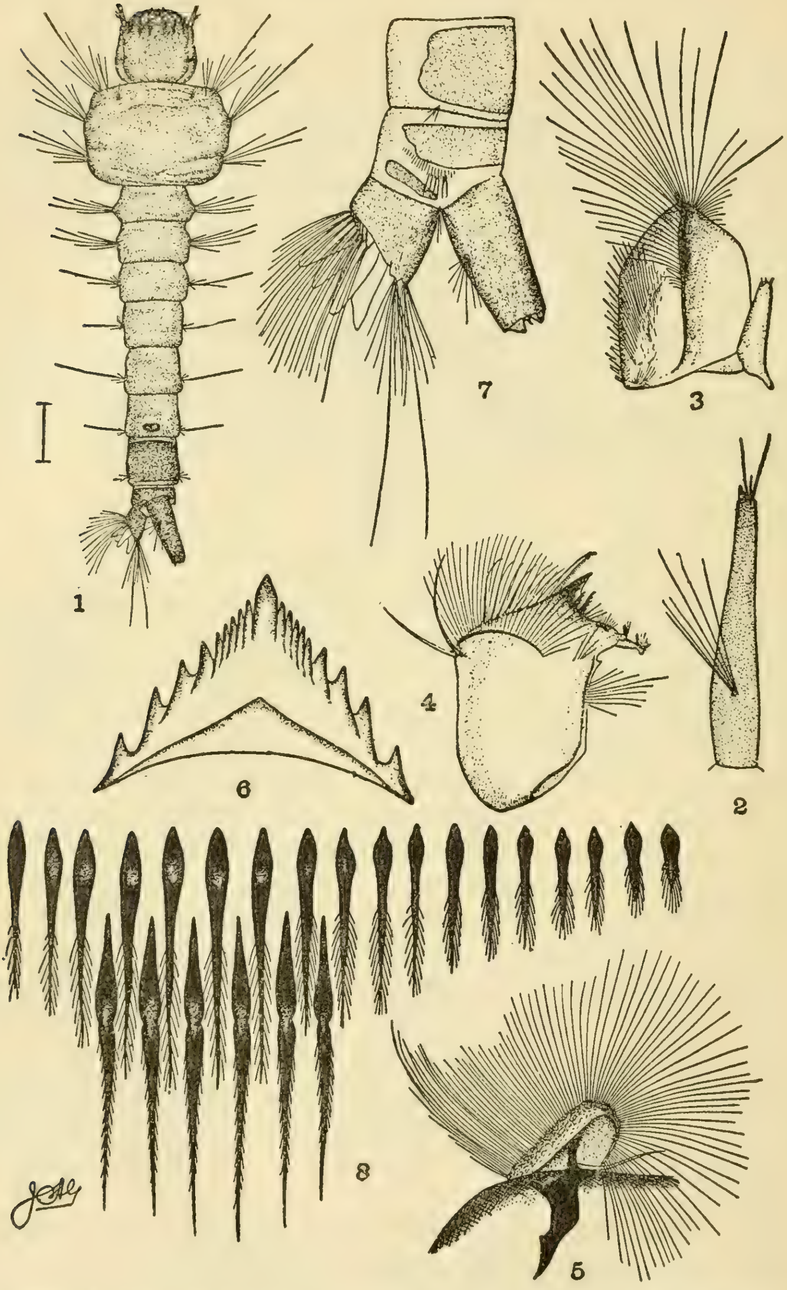


Fig. LXIV. Larva of white-lined mosquito. *Orthopodomyia signifera* Coq. (After John B. Smith.) 1, larva; 2, antenna; 3, palpus; 4, mandible; 5, mouth brush; 6, mentum; 7, terminal segments showing dorsal plates and siphon; 8, the scale patch of eighth segment (all much enlarged).

succeeding ones. Sixth segment sometimes has small, dark brown chitinized plate on dorsal surface; on seventh, similar plate covers entire surface, except slight anterior and posterior margin, and extends down sides below middle. On eighth segment plate narrowed, corresponding to smaller dorsal surface, and extends lower down sides than preceding one. Lateral combs at posterior margin of plate, but not joined to it. They consist each of two rows of scales: first with from fifteen to twenty-one greatly elongated ones, fringed laterally at basal half with fine hair, longest scales toward venter; second with six or seven scales, their apices extending between those of anterior row. Individual scales of this row much longer than any of those of first, constricted at about one-third from base; sides fringed as in others. Small lateral plate between combs and posterior margin of segment. Anal siphon about three times as long as wide, almost black, evenly tapered toward apex. Without lateral rows of spines, but has hair tuft at about middle. Ninth segment small, with oblique posterior margin; double dorsal tuft and ventral brush normal, latter confined to barred area. Anal gills short, about three times as long as broad.

HABITS OF THE EARLY STAGES

Nothing is known of the egg laying habits of this species, but the indications are that oviposition is on the surface or at the edges near the surface. The larva is so characteristic and so unlike the other species of *Culex* that there should be no difficulty in recognizing it. One collector writes: "*Orthopodomyia signifera* made its appearance in small numbers among *Culex pungens* in much larger numbers. This occurred in a tub of rather foul water under an apple tree in a chicken yard. There were three developments of this species, all in the same place, although there were over twenty other tubs of water nearby." The occurrence with *pungens* in a tub indicates a surface oviposition. Although I have had pails with water of almost all degrees of foulness exposed in my back yard, I never found even a single representation of this species.

Another collector found them near Chester in a tree hollow on September 5, in company with *triseriatus*, and again on October 3. They were fully mature in both cases, and of the September lot some were already in the pupal stage, most of the adults appearing within a week. The water in which these larvae were found was not notably foul. It may be that these pools in decaying trees are the most usual breeding places and that the eggs are laid something like those of *triseriatus*. At all events several broods are indicated.

[According to Howard, Dyar, and Knab (14) the eggs are laid singly, on their sides, close to the water line on the side of the cavity containing the water. This is normally a hole in the trunk of a tree, though water barrels and similar receptacles are occasionally used. The species winters over as a mature larva.]

Psorophora ciliata Fabricius
The Fringed-Legged Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern and central United States to Central America and eastern South America from Brazil to Argentine. Trapped 301 females in New Jersey.]

By far largest of our mosquitoes, brownish black; legs clothed with erect black scales, tarsi banded at base of joints with pale yellow in front and mid-legs and with white on hind legs. Beak unbanded, thorax longitudinally marked with brown and black stripes. Abdomen unbanded, dark brown, with scattered whitish scales.

DESCRIPTION OF THE ADULT

Very large, robust, measures 8–10 mm. (.32–.40 inch) in length, excluding beak, which is 5 mm., or nearly half length of body. Head covered with mixed brown and white scales, white ones usually predominating and brown ones collected into three stripes, which extend from base of head to posterior margin of eyes. Proboscis testaceous, wholly black at apex, with scattered black scales at base, thickest at basal half and at extreme apex. Palpi in female about one-third length of proboscis, four-jointed, apical joint minute and variable in size and shape; testaceous with numerous scattered black scales. Male palpi very large, longer than proboscis by last two joints, shaped as in *Culex*, two terminal joints and apex of basal one being dilated; blackish brown in color, testaceous at base. Antennae brown in female, fuscous in male, two basal joints of the former yellowish.

Dorsum of thorax has median line of golden brown scales extending its entire length; on either side of basal fourth edged with patch of white scales; this median ornamentation bordered by lustrous, nude portion which becomes wide posteriorly. Sides of mesonotum covered with mixed white and yellowish brown scales. Pleura brownish, with scattered grayish scales. Legs pale testaceous, femora of all with few dark scales; dense tufts of black scales near apex. Tibiae of anterior

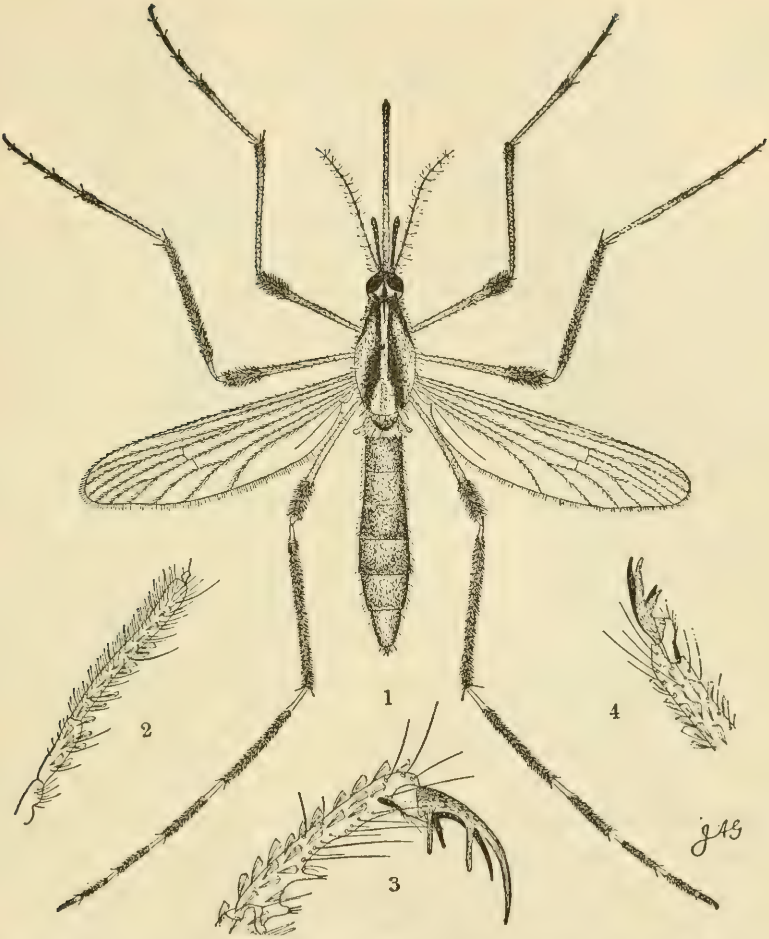


FIG. LXV. Adult of fringe-legged mosquito. *Psorophora ciliata* Fabr. (After John B. Smith.) 1, female adult; 2, palpus; 3, anterior and 4, posterior claws of male (all enlarged).

legs have many black scales, especially at apex. Those of the middle and posterior legs thickly covered with long erect black scales, except at base. First tarsal joint of anterior and middle leg pale testaceous, with black scales at apex; second joint of anterior and second and third joints of middle pair with basal bands of yellowish, remainder black. Posterior tarsi covered with erect black scales, with base of joints white-banded. Claws of male anterior and middle tarsal joints long and unequal, larger with median and basal tooth, smaller with single tooth near base; one specimen examined showed two teeth on this small claw, side by side. Posterior claws and all those of female stout, equal, with a single median tooth to each.

Abdomen dark brown above and beneath, with whitish scales irregularly scattered over whole surface, more so ventrally. Dorsal surface appears to have light colored central stripe, as light happens to strike it.

HABITS OF THE ADULT

This is the largest of our New Jersey mosquitoes and its bite is in proportion to its size, but it does not seem to be so poisonous as that of the smaller species. Clothing is little protection when it really wishes to bite, for it gets through coat, vest, and two shirts to the skin without any trouble whatever. It seems, however, that it prefers horses to humans, and it certainly never attacks in swarms. It is not averse to getting indoors if it can do so without much effort, and it is not infrequently sent in with house captures. In flight it is somewhat slow and heavy, and I doubt whether it ever gets very far away from the place where it bred.

The method of hibernation is not definitely known, but it probably hibernates in the egg stage. Adults have never been taken very early in the season, and it is not until June that the species attracts attention in any stage. It continues, however, through September and to the early days of October, so far as our records go.

It is distributed throughout the state, but is usually rare. Only on occasions when a brood has just emerged is it possible to find them in numbers. A few are taken in New Brunswick every summer. The species was commonly found at Spring Lake, near Trenton, July 2; a single specimen occurred at Hackensack, August 8; one at Jamesburg, August 16; two examples at Livingston Park, August 27, and that concludes the slip record of captures. A few examples only are taken during the summer at Lahaway. On the whole, unless one goes into the haunts of this species in the woodlands, it can scarcely be called really troublesome.

DESCRIPTION OF THE LARVA

Full grown, averages 10–12 mm. (.40–.44 inch) long, though specimens occasionally attain immense length of 15 mm. (.60 inch), exclusive of anal siphon. Usually pale gray, but sometimes dark gray. Head quadrate, widest at eyes, slightly excavated on anterior margin, pale brown, more or less blotched with dark brown spots, though often uniformly colored. Two small hair tufts of four or five hairs on vertex, near anterior margin. Antennae yellowish; moderately long and slender, but thick near base; extreme apex has two short spines and small

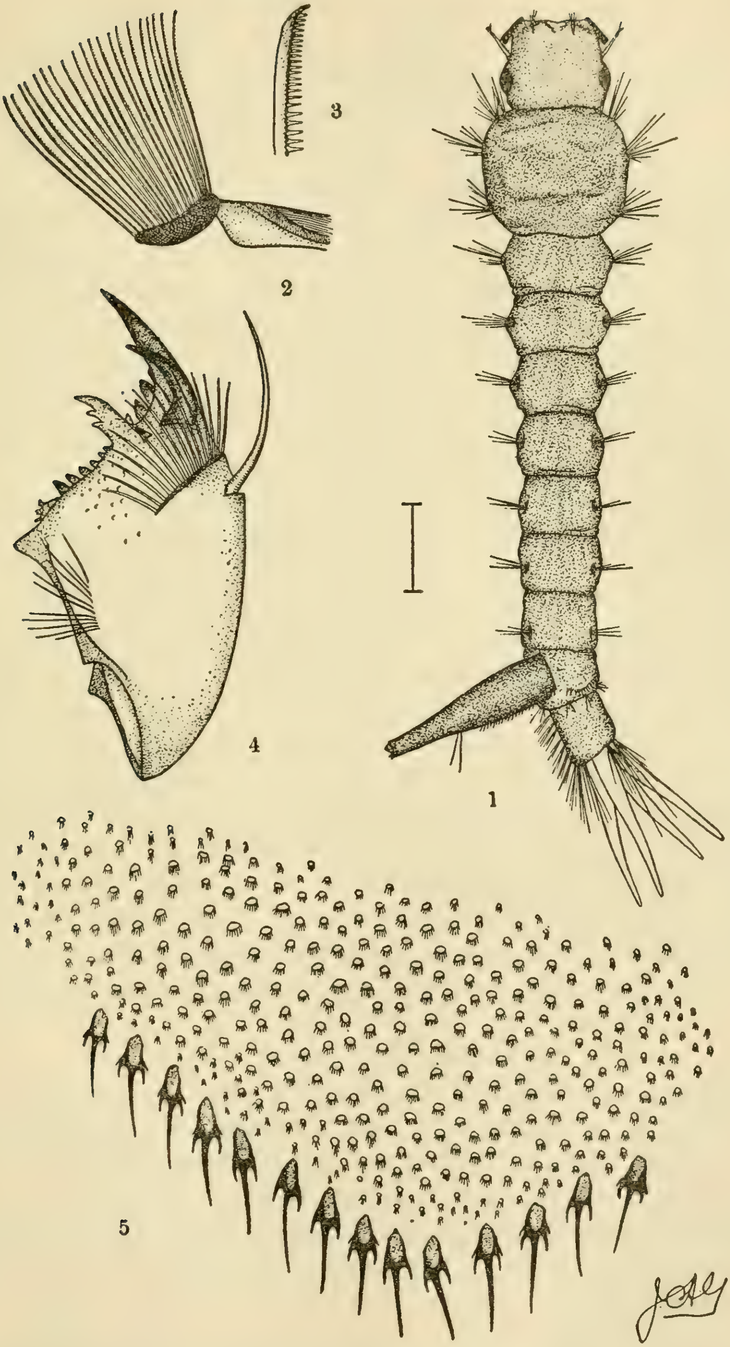


Fig. lxvi. Larva of fringe-legged mosquito. *Psorophora ciliata* Fabr. (After John B. Smith.)

joint; on slight offset near apex two other spines, one very long and one short. Few large, stout spines on basal half, and slender one, representing tuft, issues from shaft one-fourth length of antenna from apex. Eyes small, occupy part where head widest. Mouth brushes small, brown, close tightly at sides of head when not in use. Composed of stout hairs, comb-toothed at apical half. Fig. LXVI, shows one of these hairs greatly enlarged. Mentum short, very broad, with seven to nine teeth on each side of apex; apical tooth large, as are two next to basal, terminal and basal teeth smaller and uniform. Mandible triangular, longest side rounded; teeth very large; single dorsal spine. Maxillary palpus chunky, surface covered with short hairs and spines, apex with short, thick spines, basal joint small, somewhat retracted. Epipharynx and hypopharynx shown from above and below at Fig. LXVI.

Thorax almost as long as broad, not angular, with three groups of short hair tufts issuing from each lateral margin.

Abdominal segments from one to seven very stout and robust, with short tufts of hair set in small depressions at sides, each tuft of from three to five hairs, larger number in anterior segments. Eighth segment has lateral patches of scales consisting each of large patch of minute scales edged at anterior margin with single row of from ten to sixteen large scales, individual scale with long, stout apical spine, one or two smaller ones at sides. Anal siphon large, thickest near base, narrowing considerably apically, about four times as long as its greatest width. From twenty to thirty spines in each of lateral rows, single spines very long and slender, with one or two teeth at extreme base. Ninth segment slightly longer than broad, with very short double dorsal tuft and ventral brush, latter not issuing from barred area, tufts extending whole length of ventral border. Tracheal gills long, about three and one-half to four times length of ninth segment.

HABITS OF THE EARLY STAGES

The eggs of this species are laid at the edge of a pool or, perhaps more usually, in a moist depression, where they remain dormant until they become water covered. They are of considerable size, coarsely sculptured and hatch within a few hours after the pools become water filled. Eggs have been obtained from females which have been allowed to bite so as to obtain blood food, and the indications are that blood food is essential to the insect for ovarian development. Eggs and very young larvae, dipped from a pool at Monmouth Beach, were, apparently, resting loosely on the layer of bottom mud and rose when the dipping was in progress, so that quite a number were obtained.

Another collector reports the hatching of the eggs very soon after a pool becomes water filled, and the rapid development of the larva: "On one occasion it began to rain on Monday morning and water soon collected in the bed of a dried up pond. In the deepest place there was a patch of damp mud with a rotten log lying in it. On Tuesday there were thousands of *Aëdes sylvestris* larvae about one-eighth of an inch long. Pupae of both forms had developed by Friday, and on Monday all had enlarged."

The larvae are immense for wrigglers and are at once recognizable by their size. Unlike others of this series they are predatory and feed on other mosquito larvae; if there are not enough of other kinds present they turn cannibals and eat each other until some are full grown and complete their transformations. Their appetite is enormous and they feed continuously. Small larvae are swallowed entire; the larger are seized just below the anal siphon or breathing tube to choke them, and when the struggles cease are devoured to the head. The larvae are, therefore, scattered as compared with those of other mosquitoes. One collector found one to every thousand *Culex* and *Aëdes* when both occur together, but that of course is subject to any amount of variation. Another collector found pools swarming with small *Aëdes vexans* and a goodly population of *Psorophora* among them. A few days later only *Psorophora* remained, and these were scattered and difficult to find. There is no greater enemy of or more effective check to, other mosquito larvae, than *Psorophora*, and its rank as a pest is not sufficiently high to counterbalance the benefits received from it. Unfortunately it has its limitations. It occurs usually in temporary pools or in pools which have been dried out previously to kill off all fish and similar enemies, and its habits of attacking and devouring its own kind whenever opportunity offers, prevents anything like a great increase in its numbers.

As a rule, perhaps, woodland pools or those at the borders of woodland are favored as breeding places, but I have found and received larvae from more open pools, even from entirely unsheltered holes near the banks of the Raritan River, so that it can scarcely be said that this is a real woodland mosquito. There is scarcely a county in the state from which the early stages have not been sent in.

Psorophora columbiae Dyar and Knab
The Spotted-Legged Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from New York southward. Trapped 606 females in New Jersey.]

Dark, large slate colored or black mosquito. Femora and tibiae spotted with yellow, tarsi white-banded at bases. Beak has white central band, wings thickly scaled with black and white scales, giving dotted appearance under lens. Abdomen black with incomplete basal bands and C-shaped marks.

DESCRIPTION OF THE ADULT

Large, 6.5–7 mm., little over quarter-inch in length; beak about 2 mm., or slightly less than one-third length of body. Head blackish, with cinereous scales scattered over surface, forming narrow border to posterior part of eyes; proboscis black at apical third, yellowish centrally, gradually merging into black base. Palpi in female blackish, white at apex of third joint, fourth joint usually very small, with few bristles at apex. In some specimens this joint rather large, oblong, with obtuse apex. Male palpus black, only slightly dilated, basal joint has whitish band in center, is almost as long as the proboscis; terminal joint a little shorter than central one; both have narrow pale band at base. Antennae of female brown, with basal joint yellowish brown; in male brown with paler plumes.

Thorax black, generally striped appearance; absolutely fresh specimens, pinned without handling, and before they have had opportunity to denude themselves in breeding jar do not show stripes. Evenly covered with black spiny clothing, has cinereous scales, diffused over posterior part and collected into two or four spots in anterior portion. Pleura black with small patches of grayish scales. Femora black with scattered yellow scales; apex white; broad white band near apex on posterior femora, narrower band on anterior, almost none on median pair. Wholly yellowish beneath. Tibiae black with white dot at base, many white scales collected into spots on one side. Tarsi black with broad white rings at base of all joints except fifth on fore and middle feet. First tarsal joint has broad white band in the center, less distinct on middle and anterior pairs. Claws of fore and middle tarsal joints of male unequal in length, larger with median and basal tooth, smaller with basal tooth only. Posterior claws equal and simple, as all those

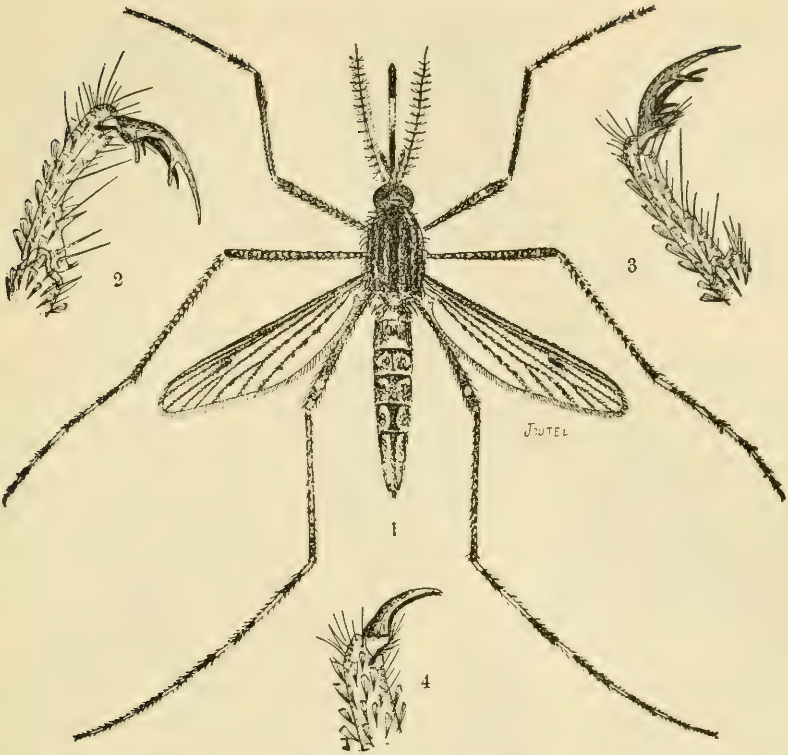


Fig. lxvii. Adult of spotted-legged mosquito. *Psorophora columbiae* D. & K. (After John B. Smith.) 1, female adult; 2, anterior, 3, middle and 4, posterior claws of male (all enlarged).

of female. Wings hyaline with veins clothed with mixed black and white scales; at base of radius 4 + 5 small portion has no white scales, making distinct black spot.

Abdomen jet black, first segment with patch of yellowish white scales in center of apical margin; second banded with scales prolonged forward in middle; following segments with two C-shaped marks, back to back, but divided by black. These marks sometimes diffused or become less curved posteriorly, until apical segments have two longitudinal marks. Brownish or slate colored beneath.

HABITS OF THE ADULT

Though this is scarcely to be considered a rare mosquito, it appears to be very local, and as an adult does not seem to get away from the immediate vicinity of its breeding pools. Although a lively breeding place is only a few hundred feet from my house, the species has never made its appearance on my porch. Adults could be collected easily enough in the immediate vicinity of the pools, but none were seen only a few feet away.

The female has fully developed mouth structures and may bite, though she is not aggressive. Reports are that the bite does not hurt at all at the time, but that the swelling and the pain develop soon afterward. Indications are that they are not common anywhere. The species winters, probably, in the egg stage, and does not become noticeable until midsummer.

DESCRIPTION OF THE LARVA

Full grown, 8–9 mm., or about one-third inch in length, exclusive of anal siphon, very stout, dirty pale yellow. Young and half grown larvae more slender and whiter except for food matter in alimentary canal, which is usually dark. Head rather long, tapering considerably toward front, uniformly yellow, without maculation. In young larvae dirty gray. In center of anterior part of vertex short hair tufts of four or five hairs each; another of same size at base of each antenna. Antennae rather short, gently curved, dilated about one-third from base, then tapering gradually toward apex; black, basal third whitish, surface with scattered stout spines. Tuft short, of about dozen hairs, situated at center, slightly nearer base, directly above dilation. Apex has three moderately long spines, shorter one and small joint. Rotary mouth brush yellowish brown, composed entirely of simple hair. Mandible normal in shape, without row of long spines on margin between apex and two curved, dorsal spines. Maxillary palpus short and broad, almost circular, with moderate apical tuft and small basal joint. Mentum almost as high as broad at base, with only slightly curved sides of from twelve to fourteen small teeth on each side of apex.

Thorax almost circular, with smooth surface, except slight depressions on anterior and posterior parts. Faint lateral angles each give rise to number of short hair tufts; several very small tufts on anterior margin.

Abdominal segments very broad in comparison to thorax, with two hairs to each lateral tuft, in two anterior segments up to seven. Tufts short in mature larva, but in young comparatively much longer and abdomen narrower. Eighth segment has six scales on each side attached to separate band, fringe-like, in form of semicircle. Individual scale somewhat variable, but always has three large spines, longest forming apex; smaller spines border sides; may be one, two, though possibly none, between larger ones. Anal siphon yellow, moderate in length, usually stout and broadly dilated near base, though specimens occur

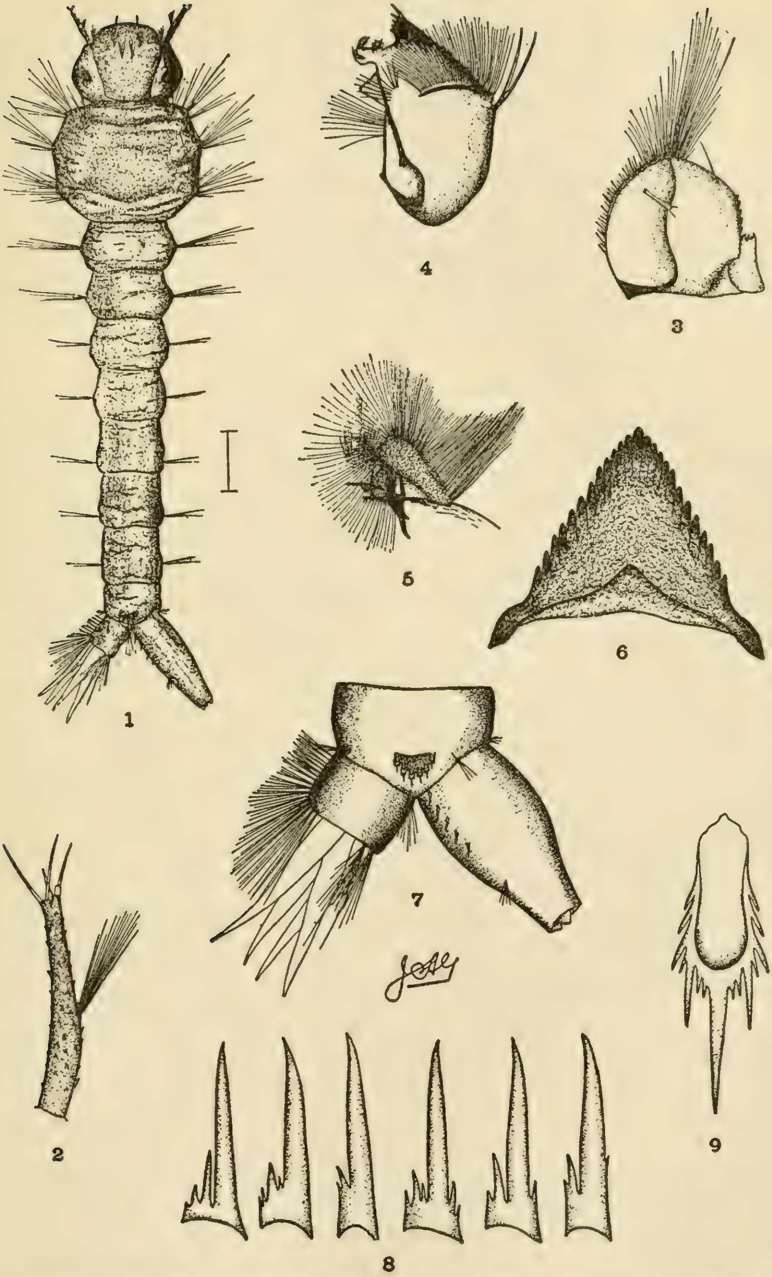


FIG. LXVIII. Larva of spotted-legged mosquito. *Psorophora columbiae* D. & K. (After John B. Smith.) 1, larva; 2, antenna; 3, maxilla; 4, mandible; 5, mouth brush; 6, mentum; 7, anal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from eighth abdominal segment (all enlarged).

where dilation scarcely perceptible. Double row of spines does not extend half length of siphon, consists of but three to five spines in each row, with small teeth crowded at base, often on both sides. In young larvae ringed near middle, the basal half whitish, apical half dark gray. Ninth segment longer than broad, with small barred area on ventral part of posterior margin from which arise rather short tufts of hair, and smaller tufts on ventral margin beneath barred area. Dorsal tufts short, each with one hair much longer than rest. Anal gills long, taper to fine point with trachea mere hair line, to be seen in living larvae.

HABITS OF THE EARLY STAGES

In New Brunswick the only breeding places known are on the College Farm, where, in woodland pools, a few specimens were taken, and two or three small temporary lot pools not far from my house. In the woods the species was associated with *vexans*, *atlanticus*, and *P. ferox;* in the lot pools with *pipiens* and *territans*. The lot pools were located in 1902, and these wrigglers could be found there at almost all times after the last days of July. In 1904 the same pools were collected over July 28, and some thirty full grown larvae were found associated with thousands of *C. pipiens*, which were collected for experimental purposes. On July 30, another lot was brought in, mostly in the pupal stage. August 9, the pools were again loaded with full grown larvae and pupae, and as specimens were needed and the pools were small, on the tenth they were collected clean. At that date there were no larvae, and the effort was to clean out the entire crop. August 17 the pools were again filled by larvae of all sizes up to the pupal stage, making less than seven days from the hatching of the egg to the pupal stage. The latter stage rarely lasts over twenty-four hours, so that a brood may come to maturity in a little over one week. August 23 all stages were again found, from young just out of the egg to the pupa.

These pools do not really differ from dozens of others in the city, and even in the vicinity, where the species does not occur. One of them becomes very foul occasionally from a sewage admixture and this seemed in no wise to discompose the insects. The others have the ordinary shale mud bottom with little or no vegetation. The larvae somewhat resemble those of *Psorophora* at sight and, as they always occurred with *pipiens*, it was believed that they might be predatory; but a series of experiments failed to bear out this belief.

Professor Glenn W. Herrick, of Mississippi, described this larva in 1904 and detailed some of its habits, which it may be interesting to quote: "I first noted the larva in an open sewage drain of the college campus in 1901. They attracted my attention by their large size as compared with the larvae in *C. fatigans*, which were so numerous in the same drain. At this time several adults were taken from the weeds and grasses overhanging the ditch. . . . In the summer of 1903, I noted scores of large larvae in a roadside pool near Starkville, Mississippi. At first sight they appeared to be the larvae of *Anopheles*, for apparently they were in horizontal positions. Never having seen *Anopheles* larvae so abundant, it seemed worth while to stop and examine them in some detail. Much to my astonishment these larvae were found to be members of the genus *Culex*, or at least of some genus closely related to *Culex*. Moreover, the great majority of them were lying apparently horizontal, just below the surface film of water. . . . From this time forth many larvae of this species were found in other rain water pools and abundant opportunity was afforded to observe them. With the one exception of those found in the sewage ditch, I have always found these larvae in transient rain water pools.

"The larvae are interesting from the position they assume in the water. When the larva rises to the surface it assumes at first about the same position as the larva of *Culex*. But after a moment, if left undisturbed, the body, with a slight jerk, floats quickly to an approximately horizontal position with the head on a level with the surface of the water, in which position the mouth brushes are able to skim the surface. The larva can change quickly and easily from the horizontal to the suspended position. The body, instead of lying nearly horizontal as does that of *Anopheles*, hangs suspended—like a piece of slack rope —between the head and respiratory tube and considerably below the surface of the water. The respiratory tube projects out of the water at least a third of its length and points forward when the larva assumes the horizontal position. . . . The larvae are splendid swimmers and are constantly swimming along the surface, but nearly always in a backward direction.

"Mr. Theobald states that the eggs, as noted by Dr. Grabham are laid singly. Although careful search for the eggs was repeatedly made, they could not be found. The larvae would invariably appear in a pool within twelve hours after the formation of the pool by a rain storm. The conviction was gradually forced upon me that the eggs were deposited in or upon the mud to await the coming of the rain."

In a general way our observations agree with those of Professor Herrick; but in New Jersey the habit of assuming the horizontal position seems much less developed. The younger larvae do assume and for a time maintain it; but when nearly mature the larvae takes the horizontal position upon rising to the surface, maintain it for a few moments only and then drop back to the normal *Culex* position. As to the oviposition, I believe that Professor Herrick is right: the eggs are laid on the moist mud very close to the edge of a pool or in the bed of an old pool itself, and there they remain until stimulated to development by a water covering.

Psorophora discolor Coquillet

The Mottled Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Southern United States to Southern Mexico. No specimens trapped in New Jersey.]

Yellowish brown, rather small, legs and beak banded, the abdomen mottled brown and yellowish white, wings spotted. Only New Jersey species in which this combination occurs; very easily recognized.

DESCRIPTION OF THE ADULT

Medium or small, not very robust in appearance. From 4–6 mm. (.16–.24 inch) long, excluding beak. Latter short, thick, excavated centrally, about one-third length of body, apical third black, central portion white, gradually merging into black at base. Sometimes white extends almost to head. Across wings averages about 9 mm. (.36 inch). Eyes meet on top of head and occupy whole anterior part. Occiput covered with yellowish scales. Palpi in female four-jointed, rather broad, terminal segment reduced to extremely small circular knob, set with hairs not as long as is usual. Palpi in male three-jointed, basal joint only slightly longer than two terminal ones together; fan-like tufts toward tip brownish black. Antennae of male plumose, brown, with usual cup-shaped segments and circle of fine hair. In female antennae shorter than beak, composed of twelve short segments.

Thorax dark brown, dorsum irregularly striped with yellow scales. Femora with mixed black and yellow scales above, wholly yellow beneath, anterior and posterior ones with pale oblique band near apex, almost obsolete in some specimens; middle femora usually without band; when present very inconspicuous. Posterior part of anterior and middle tibiae, and anterior part of hind tibiae almost wholly with yellow scales. First tarsal joint with many yellow scales to about one-third from apex, then wholly black; remaining tarsal joints white-banded

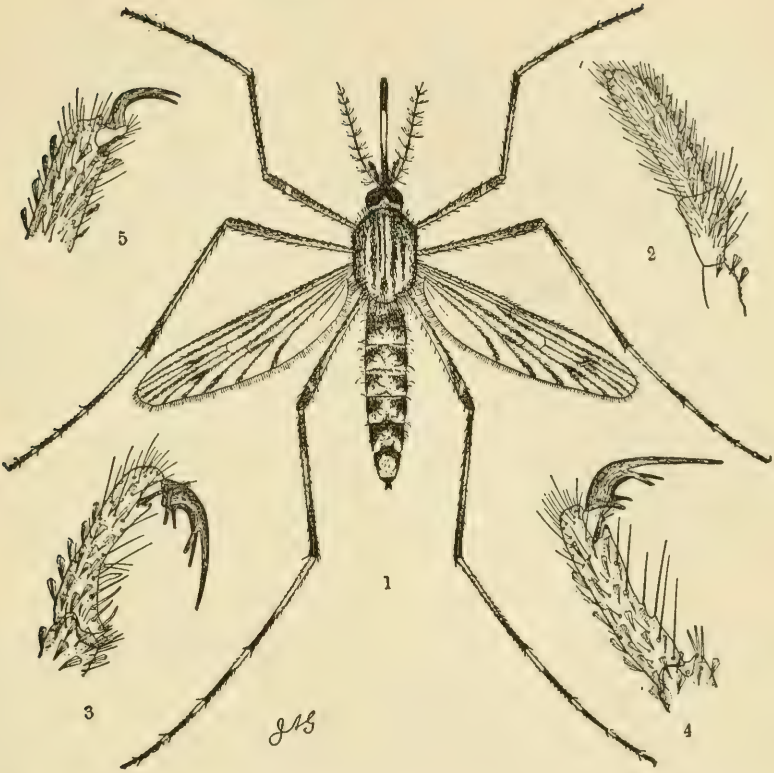


Fig. lxix. Adult of mottled mosquito. *Psorophora discolor* Coq. (After John B. Smith.) 1, female adult; 2, palpus; 3, anterior, 4, middle and 5, posterior claws of male (all enlarged).

basally, becoming narrower toward apex, last one often entirely black.

Claws of male alike in anterior and middle tarsal joints each having one long claw with median and basal tooth and shorter one with single tooth near base. Longest claw of middle tarsal joint not curved as much as in anterior one. Posterior claws small, simple, of equal length, very much curved toward base. Claws of female alike on all feet, being same as posterior ones of male.

Wings hyaline, with scales on veins collected into white and black portions as follows: costa, black centrally; sub-costa, black, outer two-thirds divided twice with white portion; radius one, basal half white, black beginning before fork with radius two, and extending to wing margin; radius two, black at basal third, also black at fork with radius three; radius three, black at basal and apical third; radius four and five, black at apical two-thirds; media one and two, black, beginning short distance from base and extending to cross-vein, black again a little on each side of fork with media three, and again at margin; media three, black at both ends; cubitus one, black, beginning short distance from base and extending to fork with cubitus two, white for short distance, then black to cross-vein, and again at margin; cubitus two, slightly black at tip and anal vein black at apical fourth. Black at forks at radius two and radius three, and at media one, two, three so close together they appear as distinct spots; others not so obvious.

Abdomen apically banded with yellowish white, bands prolonged forward in middle and intersected irregularly with dark brown of basal part; in some specimens this intersection carried further, so that brown predominates, giving abdomen mottled appearance. Sometimes brown carried across base of segment almost dividing band in two. Whitish beneath in most central part which merges into brown of sides.

We know nothing of the habits of this mosquito nor whether it bites. The adult has never been taken by any of the collectors, and from the practical standpoint it need not be considered at all, in New Jersey.

DESCRIPTION OF THE LARVA

Yellowish brown when full grown. Measures from 7–8 mm. (.28–.32 inch) in length including anal siphon, rather short and stout. Head almost as large as thorax, one and one-half times as broad as long, excavated immediately before antenna, square in front; pale yellow, without markings of any kind; from center of vertex arise four hairs, each from separate pit; tuft of four or five hairs at base of each antenna. Antenna large and white, partly covered with small stout spines, almost as long as head is broad, thickest centrally, with out and in curve, terminating almost to point. Tuft well below middle, consists of about dozen hairs. Two long spines, midway between tuft and apex, represent two of four spines which usually crown apex; apex with two short articulated spines and small joint. Eyes occupy sides of head, and are crescent-shaped, with small detached portion at posterior margins. Hairs composing rotary mouth brushes simple. Mentum triangular, broader than long, very constant in form, with eight teeth on each side of apex.

Mandible of usual form, but peculiar by possessing only single dorsal spine. Maxillary palpus scantily clothed with hair, apical tuft rather large and of long hair. Basal joint small with number of very small spines at apex.

Thorax wider than long, with rounded margins and moderately long hair tufts. When larva about to change into pupal condition, thorax becomes shriveled, dorsal surface depressed, and large prominences form on anterior margin, giving impression of entirely different species.

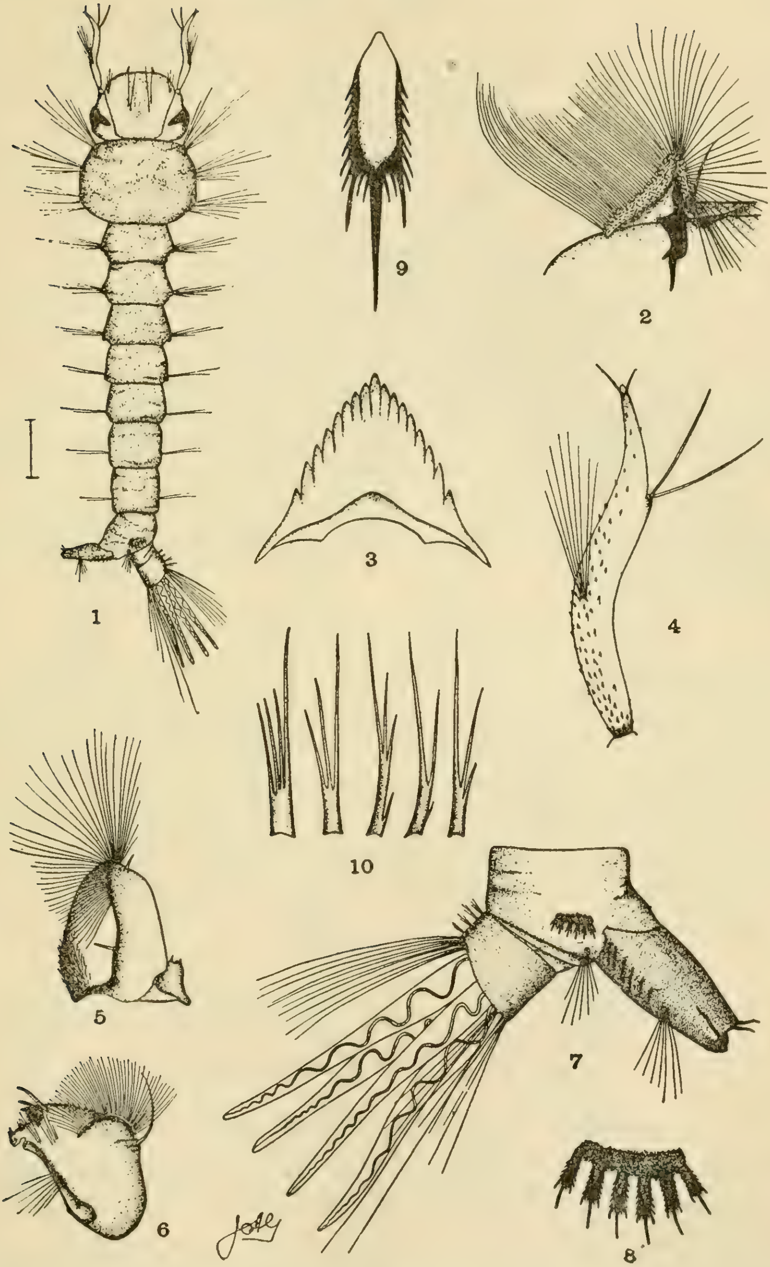


Fig. lxx. Larva of mottled mosquito. *Psorophora discolor* Coq. (After John B. Smith.) 1, larva; 2, one of mouth brushes; 3, mentum; 4, antenna; 5, maxillary palpus; 6, mandible; 7, terminal segments with siphon and tracheal gills; 8, scale band of eighth segment; 9, individual scale; 10, siphonal spines (all enlarged).

Abdominal segment one has lateral tufts of six to eight hairs each, segment two, single tuft of four hairs, segment three single tuft of three hairs, segments four and five single tuft of two hairs each, segment six no lateral tuft, and segment seven single lateral tuft. Eighth segment prolonged upward on dorsal part to receive odd-shaped base of siphon. Lateral combs consist of from five to eight scales, arranged in form of arc on separate band, fringe-like. Individual scale oblong, with three stout spines directed downward, central one very much longer than other two, sides also fringed with spines. Anal siphon very small, three times as long as broad in its greatest length, with two small, curved spines at apex; siphonal tuft exceptionally large, consists of from six to eight hairs. From five to eight spines in each lateral row, all with two or three long teeth. Ninth segment transversely oblong, widest at dorsal part, with usual double tuft of hairs. Barred area of ventral part small, has only three or four tufts of long hair and row of very short tufts. Anal gills long, twice as long as siphon, and provided with obvious tracheae.

HABITS OF THE LARVA

The larvae, received first at the laboratory on June 20, 1903, attracted attention first by their unusually prominent, white antennae; second, by the very long anal gills; third, by the habit of resting on the bottom, back down, antennae pointing upward and mouth brushes kept in constant motion. Pupae were formed June 23 and 24, and on the twenty-seventh and twenty-eighth adults emerged, a pupal period of four days. The larvae are rare, and remain below the surface, feeding at or near the bottom.

Psorophora ferox Humbolt
The Big Woods Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Southern Canada south through eastern United States, Mexico, Central America, South America, and West Indies. Trapped twenty females in New Jersey.]

Rather large or medium sized, black with deep purple sheen. Beak and legs black, hind legs heavily scaled, last two tarsal joints and part of preceding one white. Thorax with pale yellowish scales scattered over black background, abdomen unbanded. Very characteristic mosquito, recognized at glance by metallic purple sheen and white hind feet.

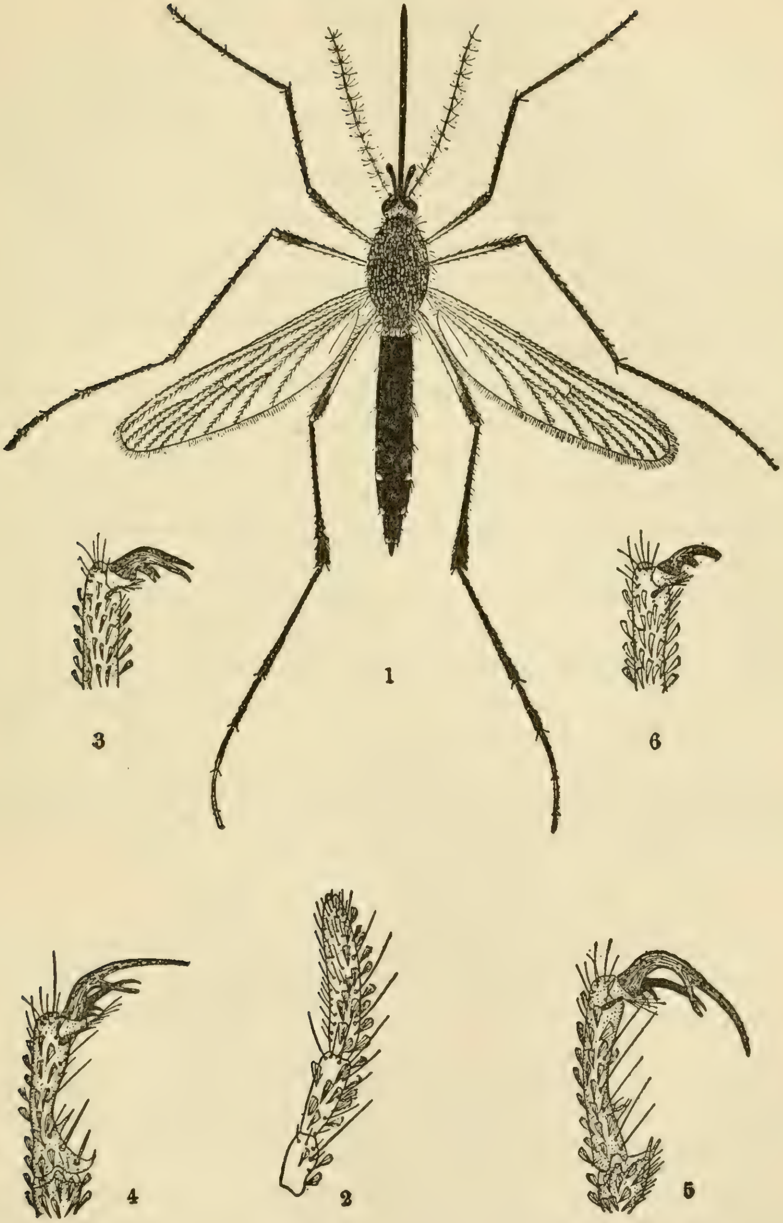


Fig. lxxi. Adult of big woods mosquito. *Psorophora ferox* Hum. (After John B. Smith.) 1, female adult; 2, palpus; 3, anterior claw of female; 4, same of male, 5, middle and 6, posterior claws of male (all enlarged).

DESCRIPTION OF THE ADULT

Measures 5–6 mm. (.20–.24 inch) in length, exclusive of beak, which is about half length of body. Occiput densely covered with yellowish brown scales; proboscis black, without bands; palpi in female purplish black, rather slender, four-jointed, terminal joint minute and circular. In male palpi very long, three-jointed, longer than proboscis by two terminal joints; evenly dilated from tip of basal joint to apex; purplish, with white band in middle of basal joint, nearer base; apical two joints set with rather short hairs. Antennae dark brown in both sexes, basal joint of female yellowish.

Thorax brownish black, profusely sprinkled with creamy yellow scales, pleura dark brown with large irregular patch of grayish white scales. Femora largely yellowish, black toward apices on upper side, with white dot at knee. Tibiae and tarsal joints black with purple sheen, those of hind legs densely scaled, tibiae swollen at apex; whole of last two tarsal joints and apex of middle joint white. Claws of male anterior and middle tarsal joints unequal, larger with curved, blunt median tooth and acute basal tooth, smaller with single tooth near base, posterior claws equal, each with single median tooth. Female claws equal on all feet, anterior and middle ones slightly sinuous, with median tooth nearer base, posterior like those of male.

Abdomen deep metallic purple above, yellowish beneath, yellow extending up sides at apex of segments, showing slightly on dorsal surface at apical angles in last two or three segments.

HABITS OF THE ADULT

A collector describes the adult female as follows (the experience took place on the Great Piece Meadow about the middle of August):

"The persistence of this mosquito is almost incredible. When one invades it haunts, at first not a specimen may be seen; but in a few minutes it seems as though every individual in the locality has concentrated on one's person. Brushing them away is a mere waste of time for they return to the attack with double fury, and their bite is very painful. So eager are they to insert their lancets that they can be very readily taken with vials, and in one hour I took 100 specimens in this way. Working pools for larvae, with both hands occupied, in a locality where they are present, is most unbearable, for with the hands wet their reluctance to leave is still greater and they may be crushed by simply laying the finger upon them. At one time a mosquito rested upon the back of my hand and before she got a hold I disturbed her by sliding my finger towards her; she rose hastily about four inches and immediately descended on the same spot; nine times was this repeated, the insect each time rising four or five inches and alighting within half an inch of the same spot; the tenth time she moved about two inches and I let her get a good bite, then disturbed her in the same way. As fast as I could remove my finger she was back again and only lost heart at the nineteenth time when she flew on my clothing and was bottled."

The testimony of the other collectors is the same, and there is no doubt that this species shares with *Aëdes aurifer* the first rank for persistence in the mosquito tribe.

The species is not an early one and the first outdoor captures were made June 30 and as late as September 9. Some collections have been recorded from New Brunswick, Little Ferry, Hackensack, and Great Piece Meadow. The species seems to confine itself to wooded areas exclusively and to prefer those which are low, swampy, and cold. None of the collections made indicate that it is at any time a house mosquito.

As to the matter of hibernation nothing is really known so far as I am aware. It is probable that the winter is passed in the egg stage and possible that the egg may become dry at times; but none of the other species known to me as egg hibernates make so late a start in the spring as this species seems to do.

The egg laying habits have been observed by Dr. J. W. Dupree, of Baton Rouge, Louisiana, and recorded by Professor H. A. Morgan. A female specimen captured April 30 was permitted by Dr. Dupree to feed upon his hand until fully engorged. On the morning of May 1 forty eggs were found, some at the bottom of the glass containing the water, while others were resting upon some fibers of cotton which had accidentally fallen into the vessel. Dr. Dupree thinks it altogether likely that the eggs, which are deposited singly, under normal conditions rest upon floating debris.

DESCRIPTION OF THE LARVA

Full grown, measures 7–8 mm. (.28–.32 inch) in length, exclusive of anal siphon, body slate gray to blackish. Young and half grown specimens whitish to pale gray. Head large, slightly smaller than thorax, widest at eyes, a little excavated immediately before antennae, rounded in front; pale yellow, usually immaculate, at times faint clouds, or distinct brown spot in center of vertex. Four hair tufts of two hairs each, in pairs widely apart, arise from central part of vertex, a larger one of five or six hairs at base of each antenna. Antenna very long and slender, sharply curved a little below middle and tapered evenly toward apex;

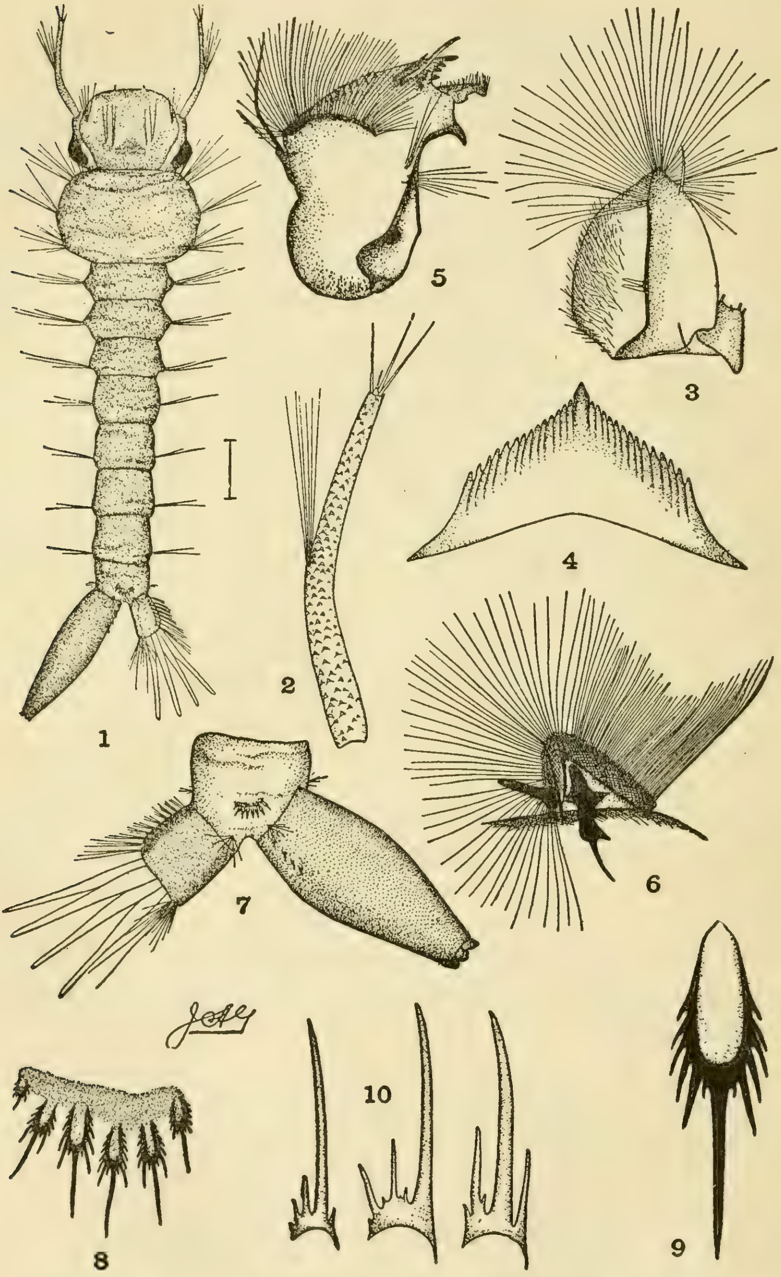


FIG. LXXII. Larva of big woods mosquito. *Psorophora ferox* Hum. (After John B. Smith.) 1, larva; 2, antenna; 3, maxillary palpus; 4, mentum; 5, mandible; 6, maxillary brush; 7, terminal segments and siphon; 8, band of scales; 9, individual scale; 10, siphonal spines (all much enlarged).

whitish at base, becoming brown apically; surface thickly set with broad spines of which bases prolonged, giving antenna scaled appearance; tuft situated on curve at middle, consists of six or eight hairs; apex has three long spines, one very short one and small joint. Rotary mouth brushes large, wholly composed of simple hair. Mentum broadly triangular with large apical tooth and thirteen to fifteen small ones on each side. Maxillary palpus normal with short, stout basal joint, mandible peculiar by deep indentation on dorsal surface, by reduction in size of one of curved dorsal spines and by having row of papillae instead of spines between large dorsal spines and teeth.

Thorax broader than long with lateral hair tufts short and wholly destitute of tufts on anterior margin.

First three abdominal segments transversely oblong, remainder subquadrate, each with two hairs to lateral tuft except in three anterior segments; these with three or more. Eighth segment bears lateral combs; scales composing them each with a long apical spine and short lateral ones attached to separate band, fringe-like, six or eight scales on each band, central ones large and long, lateral ones small and broad. Anal siphon very large, greatly dilated in center, tapering rather acutely toward apex; each of lateral pectens have three or four spines, single spine slender, with broad base and number of long and short upright basal teeth, on one or both sides of main spine. In small larvae siphon proportionately much larger and paler. Ninth segment almost twice as broad as long, completely ringed by chitinized saddle; fourteen or fifteen short tufts of ventral brush confined exclusively to ventral margin, each issuing from distinct pit, rather than barred area, which is present as mere rudiment at apex. Double dorsal tuft very small, anal gills long and slender, not over twice length of anal segment.

HABITS OF THE EARLY STAGES

"The eggs," according to Professor Morgan, "resemble somewhat in shape those of *Aëdes aegypti* though larger. Short spines pointing toward the so-called head of the egg are uniformly distributed over the entire shell. The egg has a flat and a convex surface, and with the latter uppermost presents a distinctly fusiform shape. Unless debris or a strong film floats upon the surface of the water, all the eggs sink to the bottom of the vessel, which accounts, no doubt, for the irregular periods of incubation. Of the forty eggs deposited during the night of April 30, a few hatched on May 15, others hatched May 30, and still others of the same brood on June 10. It will be seen from this that a wide range obtains as to the period of incubation.

"The larvae are active at the surface of the water for the first twenty-four hours, after which they move to the bottom when disturbed and can remain there as long as forty-seven minutes without coming to the surface for air.

"The larvae are not 'wrigglers' in the true sense of the term. They jerk characteristically when suddenly disturbed, but ordinarily move from the top to the bottom of the vessel at an angle of about 45°, with little motion save the rapid movement of the oral cilia. The passing of the larvae from the top to the bottom of the water with apparently little effort gives them a graceful appearance. While at the bottom of the glass they catch large bundles of spirogyra, which are broken into smaller pieces as the surface is approached."

The earliest larva taken in New Jersey was at Hemlock Falls, June 20. It was next found in a large woodland pool with partly rocky bottom, on the Garret Mountain, near Paterson. On June 30 larvae were taken from the South Orange Mountain, from which adults were obtained July 2 and 3. On July 15 larvae occurred at the College Farm and near the old copper mines at Arlington. August 8 there was another brood at the College Farm, and on the fifteenth others were taken at Livingston Park. During this month the adults were found in the Great Piece Meadow, and during September large numbers of larvae in the woodland pools there and in the Troy Meadows. As late as September 30 the larvae were found in numbers, full grown and ready for the change. Pupation began October 1, and the first adult occurred October 4. Development during the summer is very rapid, but in late fall it becomes much slower.

Altogether, while this species is sometimes common and bites hard, it can scarcely be considered a pestiferous species, because it does not leave the woods and breeds only in such swampy areas as are not often visited.

Uranotaenia sapphirina Osten-Sacken

The Sapphire-Lined Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Eastern United States from New Hampshire to the Gulf of Mexico, Florida, and Cuba. Trapped 1,850 females in New Jersey.]

Small dark brown with beak and legs unbanded; large white dot at apices of femora and tibiae. Thorax marked with metallic blue spots;

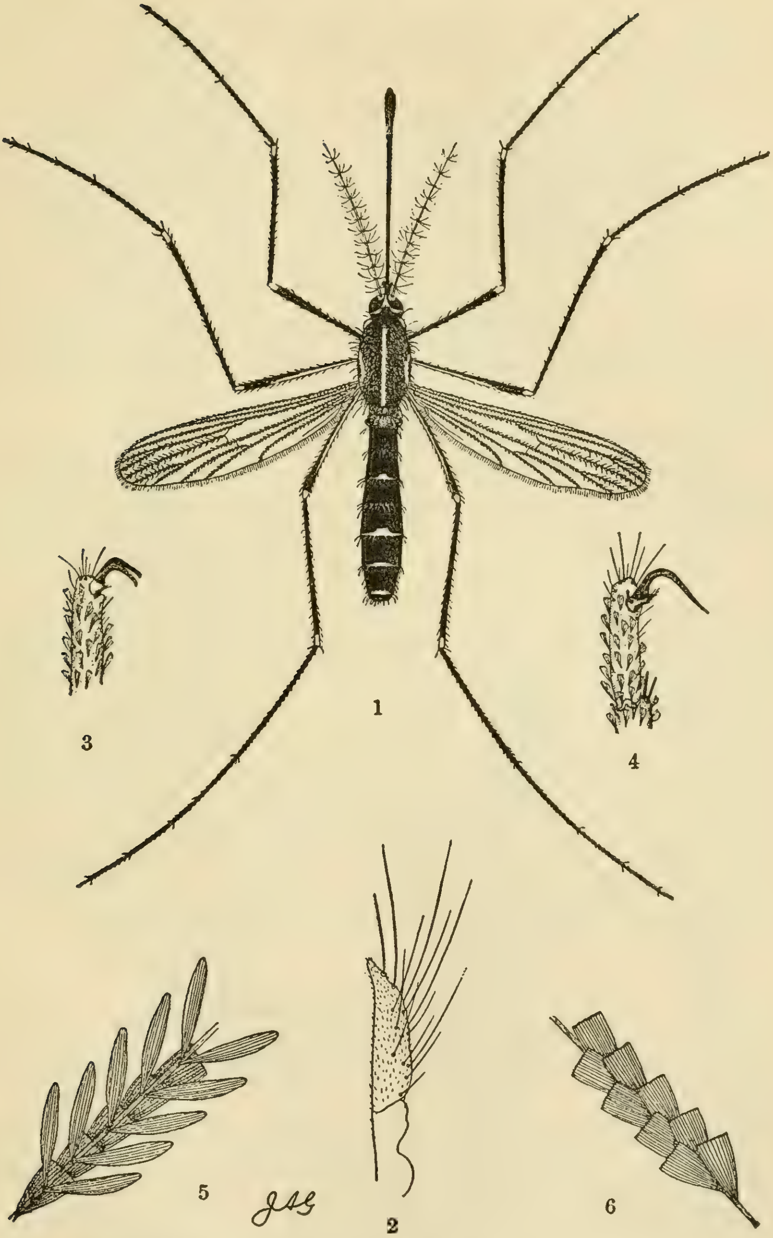


Fig. lxxiii. Adult of sapphire-lined mosquito. *Uranotaenia sapphirina.* O. S. (After John B. Smith.) 1, female adult; 2, palpus of same; 3, anterior and 4, middle claws of male; 5, part of wing vein near outer margin; 6, part of wing near costa showing scales (all enlarged).

narrow blue line down center of dorsal surface. Abdomen narrowly banded at apex of some of segments. Wings unspotted.

DESCRIPTION OF THE ADULT

Very small, measuring 2.5–3 mm. (.10–.12 inch) in length, with beak almost two-thirds length of body. Head black, with patch of metallic blue scales in angle formed by eyes, often patches of similar ones on posterior edge of eyes, which join anterior patch; palpi alike in both sexes, short and two-jointed, apical joint with long bristles; proboscis brownish, hairy, and swollen at tip. Antennae in female pilose, brown, with large basal joint yellow; in male plumose, dark brown, with paler plumes.

Thorax brown, has many long, black, curved bristles; median narrow line of metallic blue scales extends whole length of mesonotum, not quite reaching anterior margin, short, blue, curved line slightly anterior of each wing. Patagia wholly covered with blue scales, appear as lobes from above. Pleura light brown, with two small patches of blue scales, very often connected. Legs jet black, appearing dark blue in some lights, whitish on under side of femora, with large white dot at apex of femora and tibiae, which have delicate tinge of blue. Claws of anterior tarsal joint of male equal, outer half sharply curved at right angles to base, middle tarsal joint has single long curved claw set in joint below apex, posterior same as those of anterior, but smaller. Claws of female same as in male, except that middle are like anterior.

Abdomen dark brown above, paler beneath, with whitish apical bands on dorsal surface prolonged forward in middle on some of segments, largest on segments three and five in all specimens examined.

HABITS OF THE ADULT

There is no record or evidence that it has bitten or can bite. It occurs, probably, throughout the state. The dates are always after midsummer.

There is absolutely no chance of mistaking this little species when it can be seen under a sufficient magnification to bring out the sapphire blue scales and lines on the sides and top of the thorax.

How the winter is passed, we do not know; but it would seem as if this were a species that might live over in the adult stage. The eggs, forming a floating mass on the surface of permanent water bodies, are not well adapted to live through in that shape, the larvae have never been found in winter and their surface habit opposes the suggestion that they could withstand the rigors of winter.

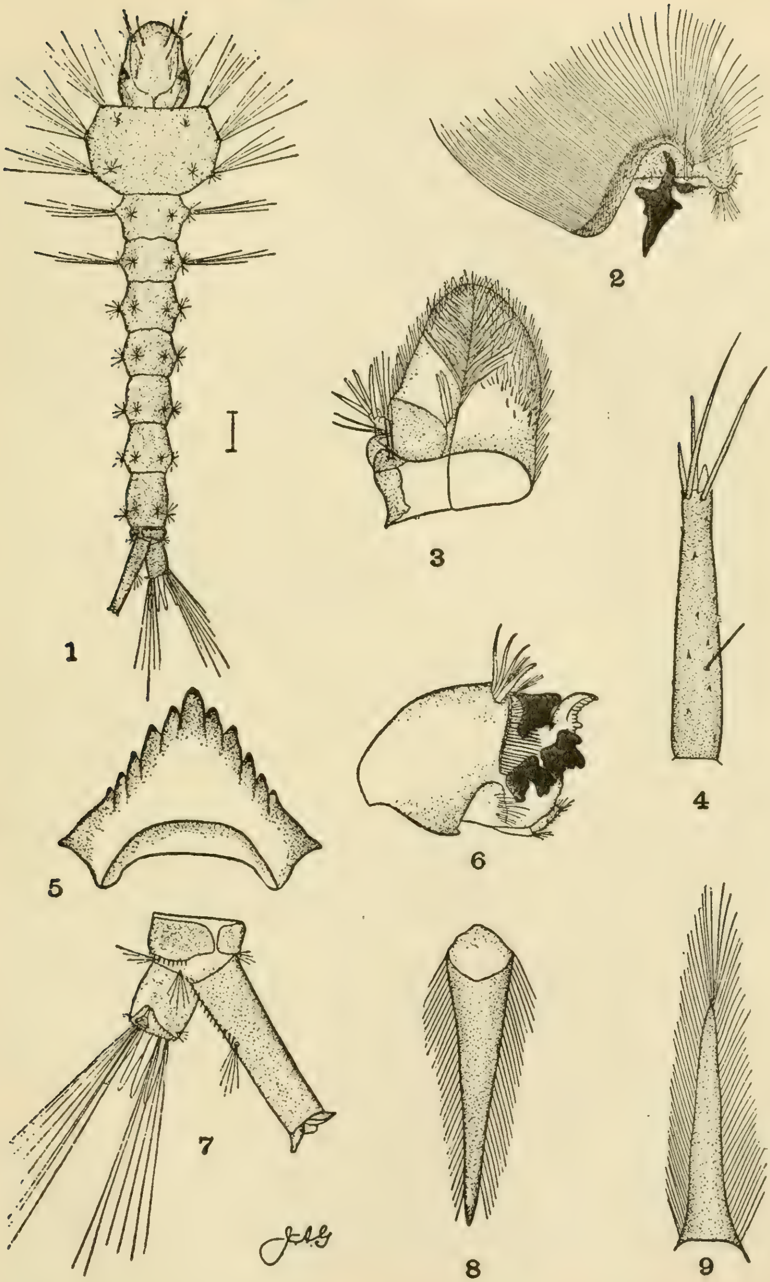


Fig. lxxiv. Larva of sapphire-lined mosquito. *Uranotaenia sapphirina* O. S. (After John B. Smith.) 1, larva; 2, mouth brush; 3, palpus; 4, antenna; 5, mentum; 6, mandible; 7, terminal segments and siphon; 8, a single scale from eighth segment; 9, a siphonal spine (all enlarged).

DESCRIPTION OF THE LARVA

When full grown 5–5.5 mm. (.20–.22 inch) in length to end of ninth segment; yellowish brown or grayish. Head small, elongated, broadest immediately behind eyes, excavated little before antennae and rounded in front. Generally an even dark brown, though often irregularly marked with yellow or pale brown. Four stout setae arise from vertex in anterior part, each from separate pit, pits so arranged as to form squares; small tuft of four or five hairs also at base of each antenna. Antennae uniformly brown, rather short, sparsely set with short spines, terminating with two very long spines, two shorter ones and small joint; tuft represented by single stout seta situated one-third from base. Rotary mouth brushes small, composed of simple hair. Mentum triangular, very chunky, with nine or eleven blunt teeth, largest at apex, smallest toward base. Mandible and maxillary palpus also both chunky, former peculiar by group of blunt black teeth and four dorsal spines, one of which finely comb-toothed, while latter has no apical tuft, but thickly clothed with short hairs, basal joint small, with four very long, blunt terminal spines.

Thorax angular, at least one and one-half times as broad as long, each lateral angle giving rise to long hair tufts. Two smaller tufts on anterior margin and six stellate hairs, two in anterior part and four in posterior part on dorsal surface.

Abdominal segments subequal, rather deeply constricted at sutures. Lateral prominences of anterior two segments have each about four long hairs, following segments with only short stellate hairs at sides. On dorsal surface each segment has two other stellate hairs, in addition to lateral ones. Eighth segment has large lateral plates, with row of six to nine stout spines on posterior edge, each spine finely fringed with hairs at sides. Anal siphon three to three and one-half times as long as broad, only a little narrower at apex than at base, slightly concave; apex with four processes, so dilated as to flare at tip.

Lateral rows of spines composed of from twelve to fourteen each, single spine destitute of basal teeth, but fringed with fine long hairs at base and apex. Ninth segment longer than broad, with anal gills about as long as this segment; double dorsal tuft and ventral brush composed of long hairs of equal length, latter very small confined to barred area.

HABITS OF THE EARLY STAGES

Dr. Smith quotes Dr. Dyar's description, with which he agrees: "The eggs form a boat-shaped mass floating on the surface of the water, much as in *Culex pungens*, but the mass is smaller, containing a less number of eggs and is less regularly elliptical, more angular. It floats less on the surface, the middle eggs being nearly half submerged. The sculpture and color of the individual eggs are also different. The newly hatched larva at once takes up the usual feeding position. This is essentially as in *Culex*, but the body is held more flatly, more parallel to the surface, yet below the surface film. Consequently, though feeding as *Culex*, the larvae resemble *Anopheles* at a casual glance and were several times at first mistaken for them. The larvae are fond of resting below the leaves of the *Lemna*, where they remain with the air-tube penetrating the surface and feed, often with a rotary motion of the body on the air-tube as an axis. Occasionally they bend up to feed at the surface. They are not timid and often a considerable commotion of the water is necessary to send them to the bottom. The head may be partly rotated on the neck, but the habit is not so completely developed nor so frequent as in *Anopheles*, which regularly feeds with the heads inverted. It has an elongate, dark brown head with a contrasting pale body, the hairs of the anterior abdominal segments markedly longer than those of the succeeding ones. Of the local species (at Bellport), it most suggests the species of *Anopheles*, as above noted. The long anterior hairs assist in the deceptive appearance. There seem to be four larval stages, the last three being essentially alike, except for the successively larger size. This is shown best by the head as in Lepidopterous larvae. The head gradually becomes paler, being black in the young larva and brown in the large ones. The pupa resembles that of *Culex*, but is very small and has unusually long air-tubes. The species seem to breed continuously all summer, preferring warm, stagnant pools of some size, containing *Spirogyra*."

At Lahaway I found the egg boats near the shallow edge of a large fish pond and the larvae among the vegetation along the shallow edge of a lily pond in late June. Larvae also were found in Cadwalader Park, Trenton, August 5; at Metedeconk, September 23, and at Irvington, September 15. It is what is called a local breeder, being found in about the same places each year and always in permanent bodies of water.

The resemblance to *Anopheles* with a long breathing tube is so strong that I could scarcely persuade myself when I first saw the larva that it did not belong to that genus.

Wyeomyia smithii Coquillet
The Pitcher Plant Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Canada to Alabama and probably covers the same range as its host plant, *Serracencia purpuria*. Howard, Dyar, and Knab report it as the only sabethine mosquito living in temperate latitudes. Seven specimens have been trapped in New Jersey.]

Small, black, with abdomen, legs, and proboscis unbanded, and wings unspotted. Whole under surface, including sides of thorax and part of under side of legs yellowish or silvery white, strongly in contrast with black upper side.

DESCRIPTION OF THE ADULT

Very small, measuring, exclusive of beak, 3 mm. (.12 inch) in length. Proboscis comparatively very long, being two-thirds length of body; black, slender, slightly swollen at apex. Head and eyes jet black above; beneath silvery white scales extend up posterior border of eyes and approach slightly on dorsal part; very small patch of similar scales on anterior part of head in angle formed by eyes. Rarely these scales diffused and form indistinct border to posterior margin of eyes. Palpi short in both sexes, shortest in male, composed of three segments each, apical one long, basal ones small with weak sutures; brownish black, sparsely set with bristles, one directly on apex, scales do not cover surface densely. Antennae fourteen-jointed, precisely the same in both male and female, penultimate joint slightly longer, apical one twice as long as others. Almost black, pale at base, set with basal whorls of long bristles which become gradually shorter toward apex.

Thorax evenly blackish brown, rather sparsely covered with short concolorous hair; occasionally grayish scales diffused over surface or collected into irregular stripes. Pleura pale brown with several small patches of silvery white scales, one small patch of bright violaceous ones in anterior angle. Legs black, with under side of femora and tibiae light yellow, tarsi black with brassy yellow sheen. Claws of anterior tarsal joint in male equal and simple, those of middle tarsal joint unequal, larger very long and curved, about one-fourth its length, straight and very acute; posterior claws like anterior, but smaller. Female claws same as in male except that middle claws are like anterior ones.

Abdomen swollen posteriorly, brownish black on dorsal surface, with metallic bronze sheen. Venter yellowish, densely covered with silvery

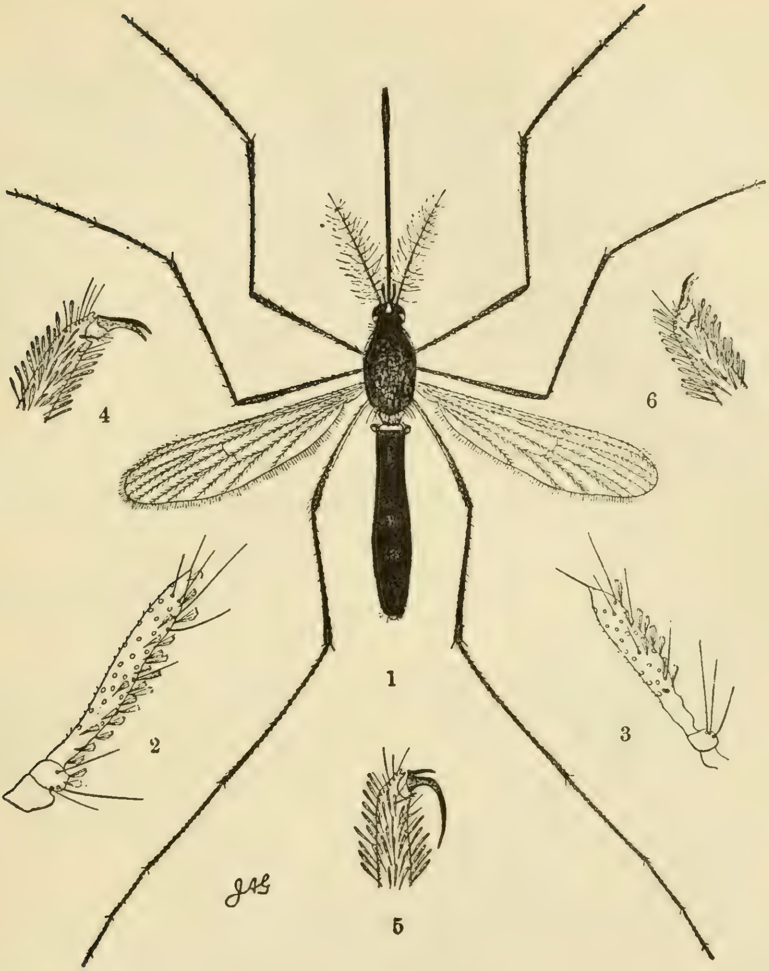


Fig. lxxv. Adult of pitcher plant mosquito. *Wyeomyia smithii* Coq. (After John B. Smith.) 1, female adult; 2, palpus of same; 3, palpus of male; 4, anterior, 5, middle and 6, posterior claws of male (all enlarged).

white scales which join brown in well defined line at sides; sometimes white extends very slightly up base of segments, but never visible from above.

HABITS OF THE ADULT

The most characteristic habit of the adult is its inability or disinclination to bite and suck blood—of human beings at least. A collector has been in the bogs and swamps where there must have been hundreds of them and never a one has come to disturb him. He has even seen them about, among the pitcher plants, apparently engaged in ovipositing, and they paid not the slightest attention to him.

Since the spring of 1901 hundreds of specimens have been annually bred in my laboratory and often examples escape. On one solitary occasion a specimen alighted upon my hand resting on the back of a chair, and I kept very quiet for several minutes watching it. It moved about a little, touched the surface with its beak several times with a sort of jabbing motion; but made no real attempt to puncture. It tried to assume the resting position but seemed to be annoyed by the hair on the hand and after shifting about for a little flew away to seek more satisfactory quarters. It is the first and only time that a New Jersey mosquito of any kind declined the opportunity to feast upon me!

The resting position, incidentally, is peculiar; the head points downward at an angle between the front legs, and the hind legs are curled over so far as to give the insect the appearance of attempting a somersault and being caught midway in the attempt.

The adults do not make their appearance under natural conditions until the end of May, and issue irregularly until the end of October or even early November.

They are found throughout the southern part of the state wherever the pitcher plant grows; but the larvae do not seem to inhabit pitcher plants in the Passaic swamps so generally. We have found them only in 1904 and then not common. Just why they should not occur there so abundantly I am unable to say, unless these northern swamps are enough colder in summer to prevent free development.

Nothing has been observed as to the length of adult life and nothing is known of their feeding habits. They have been seen apparently ovipositing during the day, but never in large numbers. I have never found them on flowers and the inference is that they are, under ordinary conditions, active only at night.

There is little or no difference in appearance between the sexes.

DESCRIPTION OF THE LARVA

When full grown averages 5–6 mm. (.20–.24 inch) in length, excluding anal siphon, many specimens attain length of 7 mm. Creamy white with head slightly darker. Head rounded, pentagonal, almost as long as broad. Antennae small, uniformly pale brown, tuft represented by single hair which issues from shaft slightly over one-fourth its length from apex; apex with several small spines and one longer one. Eyes very small, round, but often (especially in large larvae) have crescent-shaped mark immediately before them. Rotary mouth brushes bright

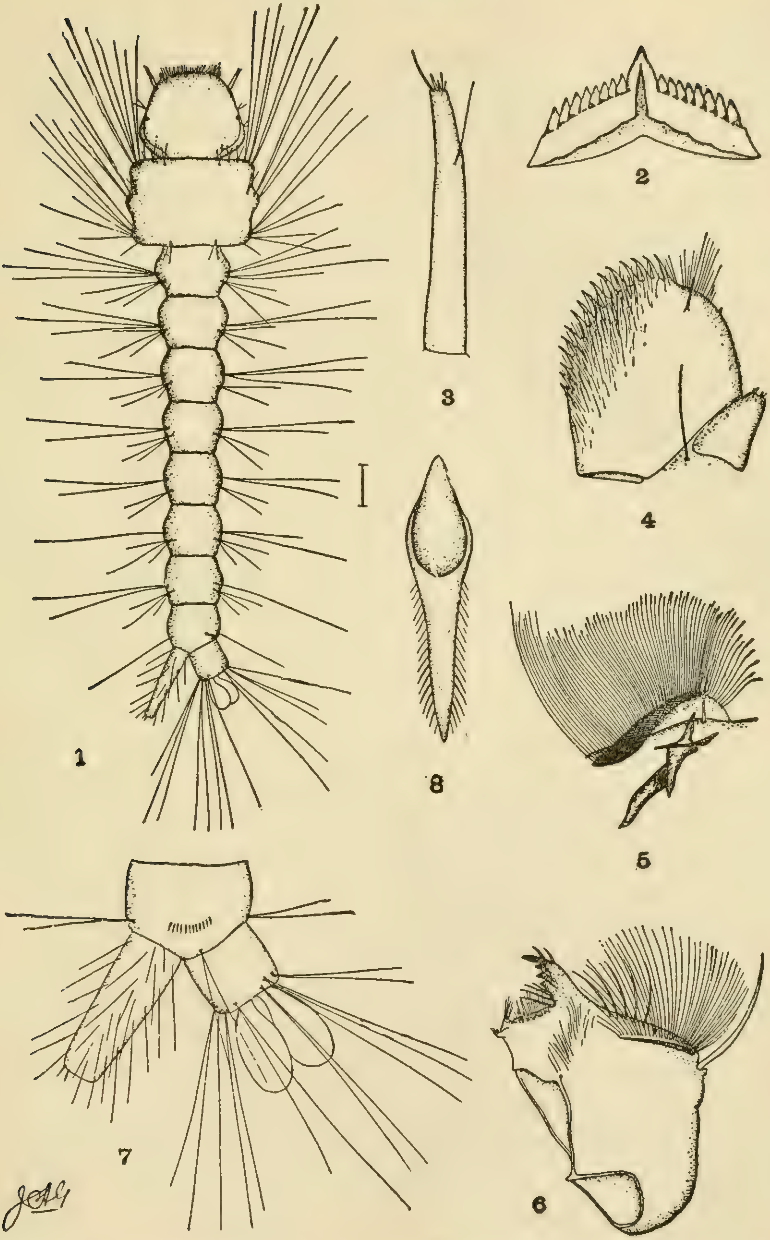


Fig. lxxvi. Larva of pitcher plant mosquito. *Wyeomyia smithii* Coq. (After John B. Smith.) 1, larva; 2, mentum; 3, antenna; 4, palpus; 5, mouth brush; 6, mandible; 7, terminal segments with siphon; 8, a single scale from eighth segment (all enlarged).

yellow, hairs composing them pectinated at extreme tips and mentum broadly pentagonal, concave at base, with large apical tooth and from seven to ten uniform smaller ones on each side; nine being usual number. Palpus longer than wide with rudimentary apical tuft, stout basal joint, and row of acutely pointed processes on one side. Mandible shaped as in *Culex*, but has only single curved dorsal spine, and is excavated between this spine and apex. Thorax quadrate, broader than long, has sinuous lateral margins, each with three groups of long hair tufts; several short ones on the anterior and posterior margins.

Abdomen slender, segments similar, with long lateral hair tufts of four or five hairs to each tuft in anterior segments, two or three in posterior ones. Number of shorter tufts below and above these long ones on each of segments. Lateral combs of eighth segment consist, each, of eleven to fifteen scales arranged in single row, individual scale elongated and fringed with short hairs at sides. Anal siphon four to four and one-half times as long as broad at base, tapers evenly toward apex. Creamy white, apex brownish; lateral rows of spines entirely absent, surface set with numerous long hairs scattered unevenly. Ninth segment almost square, with tufts of long hair on apical margin and two small processes representing gills.

HABITS OF THE EARLY STAGES

My first acquaintance with the insect began in late November, 1900, when Mr. Brakeley called my attention to the fact that, in the pitcher plants in the swamps surrounding his cranberry bogs at Lahaway, there were what he thought mosquito larvae. The matter did not interest me very strongly at the time; I assumed that it was *pipiens*.

Though the weather was yet mild, mosquitoes were no longer obtrusive. There were occasional specimens to be sure, but they seemed to be left-overs, not yet in hibernating condition. The species, unfortunately, was not determined; I was not yet, at that time, a mosquito crank. The interesting point was that in every leaf examined there were wrigglers, varying in size from an eighth to a quarter-inch in length. There was always a mass of insect fragments at the bottom, say from one-half to an inch in depth, and in composition this varied from a dense black ooze at the lowest point to entire or only partly decayed specimens at the top of the mass.

The matter dropped here until January, 1901, when Mr. Brakeley, who believes that nature wastes nothing, not even mosquito wrigglers, made an investigation of swamp conditions during a bitter cold spell. He cut out a few of the pitcher plant leaves, stripped them from the core of solid ice that they contained and, looking through it, saw wrigglers imbedded in all parts, in all sorts of shapes; but mostly in a half coil. The temperature had been down to two degrees below zero as registered by a standard minimum thermometer, and radiation probably lowered this even more.

A number of leaves were gathered, the cores of ice with all they contained were removed, and the lumps were placed together in a jar in a moderately warm room. The ice melted slowly, and, as the larvae were gradually freed, they dropped to the bottom where, for a time they rested; apparently lifeless. But as the amount of ice decreased, feeble motions here and there indicated a revival and, long before the lumps were completely melted, those first released were moving about actively. This, be it noted, was in water not much above the freezing point and, when the ice had all melted and the debris had settled, the larvae became busily engaged in feeding.

The specimens were sent to me as a curiosity, January 22, and arrived in very good condition. A few had succumbed to the dangers of the journey, but, altogether, there was a good lot of lively wrigglers. The bottle was nearly full of water, it had had a five-mile wagon drive over a rough road, had been transhipped no less than four times before it reached New Brunswick, and then was thrown into a delivery wagon and jolted through the city streets before it actually reached me. Under these circumstances any regular breathing of the kind usually described was utterly out of the question and the drownings should have been numerous; but really only a small number died.

At short intervals other jars were received, all out of melted ice taken from pitcher plants, until I had several hundred active wrigglers in eight different jars. Some of the leaf chunks had only ten or a dozen larvae, others ran as high as thirty or more. The jars were all placed on a counter shelf near a steam radiator, and it was expected that in a few days there would be pupae and adults. But the days passed into weeks and the weeks into months without change other than a very gradual increase in size. The larvae were just as active as could be expected and fed continuously, but they showed no disposition to change their condition.

As the fragments settled the water became clear and the larvae congregated over the sediment, feeding head down and frequently rooting into it. It was rare that an individual was observed at the surface with the spiracle in breathing position. I watched patiently for fifteen minutes at a time, without noting a single individual rising to the top and Mr. Dickerson watched almost continuously one day for two hours and declares that during that time only a small percentage of the entire number rose to the surface.

Occasionally a number of specimens would be at the surface, feeding, head up, so that the mouth brushes skimmed the surface, and these were watched on occasions for twenty minutes, without noting any attempt to assume the breathing position. In fact, during the two months that these larvae were under daily observation, the rising to the surface to breathe was the rare exception rather than the rule. Usually they were feeding, head down, over the bottom sediment, or head up along the sides of the jar and at the top. The mouth brushes serve also as organs of locomotion and the larvae were able to make their way from one point to another, without moving any other part of the body. They often allowed themselves to sink slowly to the bottom without any motion whatever, and sometimes, to sink more rapidly, curled themselves up into a ring. Occasionally a specimen got hold of a bubble of gas formed at the bottom and allowed itself to be floated to the surface. It was interesting to watch the little fellows; but as week after week passed it became just a little tedious; therefore, to hasten matters, I placed, March 1, the two jars first received on a water bath, which kept the temperature as nearly uniform as the varying pressure of the gas allowed—say, between 80°F. and 90°F.

A difference in growth was observable after a few days and on March 18 the first pupa was noticed, from which an adult was produced on the twenty-first, a period of three days. Three other pupae were obtained within a week and these changed to adults in about the same time.

March 24, I made an experiment which resulted fatally. It occurred to me that the slow growth might be due to lack of food and as Mr. Brakeley's larvae had attacked and devoured a small gnat I determined to add food to the water. Accordingly I placed a small lump of beef in each of five experiment jars. Next day at a casual glance I noted nothing unusual, but March 26, at 8:00 A.M., I found the insects at the top, tube out, and evidently in distress. I fished out all the meat particles at once, but the mischief had been done, and most of the larvae died. Evidently this species does not thrive in foul water; a fact which Mr. Brakeley determined also from his field collections.

As the season progressed more larvae were sent in, and these matured in such numbers that I was able to supply material in sufficient quantity to enable Mr. Coquillett to determine that instead of *Culex pipiens* we had a new species to deal with; one which will have to descend to posterity as a member of the Smith family, unless perchance it proves to have been previously described.

Mr. Brakeley kept a duplicate series of specimens under observation at Lahaway, and his first pupa, from larvae thawed out of ice February 17, was obtained April 16, and became adult on the twenty-sixth. This gives a period of fifty-eight days in active larval life, at an ordinary indoor temperature, or sixty-eight days if the pupal period is counted. Other pupae and adults developed and the pupal period ranged between ten and twelve days. A small lot of specimens gathered April 7, began pupating May 1, and these had an average pupal period of eight days.

Altogether Mr. Brakeley sent me, prior to May 1, some fifteen to twenty lots of larvae, numbering many hundreds of specimens. All these were kept in the original pitcher leaf water and this never became foul. It required the contents of from forty to seventy-five pitchers to make a full pint of liquid, and the larvae numbered from one to twenty or more in each leaf. Culture after culture was closed out during the summer; but though the conditions for all the larvae in a single jar were absolutely the same, the rate of development varied in each individual. One quart jar, containing nearly 200 larvae, received in early March, developed adults throughout the summer, and this was not closed out until September 13, 1901, six months after its receipt, when there were yet a few larvae, two or three pupae, and one or two adults! These larvae had been surely hatched in November, 1900, and had remained in that condition for certainly ten months, including the entire summer.

May 31, June 1, and 2, were spent at Lahaway with Mr. Brakeley, and during those days the swamps for some distance around were visited and dozens of pitcher plants closely examined.

In the areas flooded during the winter by cranberry bog operations, no larvae were found; but as soon as the flood line was passed, larvae were taken; generally half a dozen or more to a leaf. But none occurred except in the leaves. This point was tested very thoroughly throughout the season and it is absolutely certain that this little species does not occur anywhere outside of the receptacles formed by *Sarracenia*, except by accident. In the colder, shaded parts of the swamp, where springs occurred, larvae only were found. In the warmer areas pupae were common and, in some places, where water and moss surrounding the plant were actually tepid, the insects had already emerged and nothing but empty pupa shells could be found. It seems to be entirely a matter of temperature, and in some of the coldest places, no transformations would be likely to occur much before late June. It is certain that most hibernating larvae live from early November to late May or early June, a period of fully six months. No adults could be found and certainly none made any attempt to bite. Nor could egg masses or young larvae be discovered at this time. New leaves were developing and few yet contained any water. Such of these as were examined contained no insect life and only here and there one had trapped insects; none had begun to digest or assimilate the animal food.

An open swamp at the head of a cranberry bog had most of the leaves with pupal shells only, but though there must have been hundreds of adults about, not one could be found flying, nor could we stir them up. In a deep, cold, huckleberry swamp, only larvae were found. It was fair to conclude from the three days' tramp that no summer brood of larvae had yet begun, and it seemed strongly indicated that the insects would not bite, even if given the opportunity. In confirmation it may be said that late in the summer Mr. Brakeley saw specimens flying, and though there must have been thousands of others round about, none made any effort to disturb him.

July 3, the leaves contained half and full grown larvae, but neither pupae nor very small larvae. July 13, old and new leaves contained very small larvae, evidently of recent date, while the old leaves had also grown larvae and pupae. There was, therefore, a new series of larvae and probably the first summer brood. July 23, the older leaves had very few larvae, but almost as many very small as large ones. The new leaves had all stages, from very small larvae to pupae. The indications were, therefore, that the first summer brood was coming to maturity, developing in from fifteen to twenty days, while there were yet adult individuals from the winter larvae that were ovipositing. From the small number of young larvae in individual leaves, the indications were that eggs were laid either singly or in small groups.

The next sending did not come until August 21, and then there was everything from the most minute larva to pupa just ready to transform. So small were some of the larvae that I hunted for eggs or egg shells, but failed to recognize any. It is probable that the youngest larvae represented a third brood, but breeding was practically continuous, all stages being found at any time after the middle of July.

September 1, the same conditions existed and there was a large number of larvae so small that it seemed as if at least egg shells must yet remain, but none were found. Fortunately Mr. Brakeley returned to Lahaway early in this month and on the thirteenth—lucky day!—he found the eggs floating on the surface of the water in the pitcher plants.

September 14, I had an opportunity to spend a couple of hours in a swamp in the pines near Hanover Station, Burlington County, and found the pitcher plants there full of the *Wyeomyia* in all stages from babes to pupae. I collected the entire contents of the pitchers in alcohol, and found afterward that eggs were present in some numbers. But meanwhile Mr. Brakeley had positively identified them, and had even bred a lot of larvae, making the relation absolutely certain. He collected from time to time, until October 20, and found anywhere from five or six to thirty or more eggs in a single leaf. Oviposition was continuous, but on only two occasions were adults seen apparently engaged in the process. It is probable that the egg laying is done mostly at night.

After the eggs had once been identified there was no difficulty in finding them, but it was noted that in the older leaves where larvae were now most abundant, they were not so plentiful as they should be to account for the large winter supply. So attention was directed to the younger leaves, even where there was as yet no water in them. Here, it was discovered, was the favorite place for ovipositing, with this species. Eggs were laid in leaves as yet perfectly dry, at the bottom and at the sides, singly or in little groups, whether by one or more than one female was not ascertained. Of the old leaves many become imperfect in late fall and any puncture or decay allowing the water to escape would, of course, mean the death of the larvae. So the new leaves are selected and in them many more eggs were found than in the others. In one case Mr. Brakeley counted up to seventy-five, then lumped the remainder and called it 100. It is scarcely probable that any female of this species is capable of producing 100 eggs of the comparatively large size of those in question; so two at least, and possibly more females may oviposit in a suitable leaf.

Observations were continued until frost, which came unusually early in 1901. Up to November eggs were found, and early in that month a few pupae. So breeding is continued just as long as there is a chance to keep it up.

The eggs are chestnut brown in color, somewhat chunky, bean-shaped, the ends somewhat pointed, the inner margin nearly straight. There is no evident sculpture, yet when first mounted and examined under the microscope, there seems to be a somewhat irregular tessellated reticulation that disappears later, when the shell becomes more transparent.

In the previous notes it was brought out that this larva does not need to come to the surface for air as much as recorded for *Culex*. Dr. Howard informed me that a lot of larvae that I sent him later, lived for nearly two weeks under a film of oil which covered the surface of their breeding jar.

One of my students demonstrated in the laboratory a very complete tracheal system in the anal processes of the larva, so we have really a gill structure, by means of which the insect gets its supply of oxygen directly from the water.

Briefly stated, the life history is as follows: The insect winters in the larval stage, freezing and thawing as often as need be during that season. It pupates late in May and becomes adult a week or ten days later. Eggs are laid in the leaves singly or in small groups fastened to the sides or floating on the surface. The summer broods mature in about a month, and there are probably three if not four series, but the broods overlap so much that the breeding is practically continuous. Late in the season the adults select the new leaves for oviposition even if they are yet dry.

D. W. Coquillett tells me that he has the species from Florida, where it breeds in the leaves of an orchidaceous plant growing on trees.

Megarhinus septentrionalis Dyar and Knab

The Long-Beaked Mosquito

DISTRIBUTION AND CHARACTERIZATION

[Southeastern United States. No females have been trapped from 1932 to 1941 inclusive.

Large highly colored with violet, blue, white, and yellow.]

DESCRIPTION

Howard, Dyar, and Knab (14) furnish the following description:

"*Female.* Proboscis rather long, curved, tapering to a point. Palpi about two-thirds the length of the proboscis; long joint stout, somewhat compressed, with a constriction at basal two-fifths; penultimate joint stout, cylindrical, about two-fifths the length of long joint; terminal joint minute; vestiture metallic dark violet and blue, profusely sprinkled with golden scales, particularly at the sides; apices of segments pale lilac. Antennae filiform, slender, the joints subequal, with basal whorls of sparse hairs; second joint elongate, about twice as long as the succeeding one, stouter, a crest of erect dark scales along basal two-thirds; tori black with silvery pruinosity. Clypeus transverse, broadly rounded, black with silvery pruinosity. Occiput covered with flat, brilliant blue scales, ocular margins silvery; cheeks and head beneath silvery scaled.

"Prothoracic lobes prominent, covered with broad, flat, brilliant blue scales and bearing a few coarse black setae. Mesonotum clothed with small very deep purplish brown scales on the disk, a median stripe and broad stripes on lateral margins involving anterior angles, well defined, of light greenish yellow scales with iridescent luster; a sprinkling of dark blue scales among the purplish ones, particularly on the posterior region; over the roots of the wings are patches of brilliant blue scales. Scutellum brilliantly blue scaled at the middle, sides silvery blue and yellowish scaled in continuation of mesonotal lateral stripes. Postnotum dark brown, nude. Pleurae and coxae dark brown, mostly covered with silver scales with a slight yellowish tinge.

"Abdomen depressed; dorsal vestiture dark metallic blue with a greenish tinge at base and purplish at tip, eighth segment bright violet; first segment brilliant blue scaled, with silver patches at the sides; lateral margins of segments yellowish silvery, broadest near base and forming conspicuous median indentations on fourth, fifth, sixth, and seventh segments; sixth, seventh, and eighth segments marked with yellowish silver along posterior margin; venter yellowish silver scaled, with a broad median, longitudinal, deep metallic blue stripe, becoming narrow posteriorly and terminating near hind margin of seventh segment; eighth segment with numerous yellow apical setae; no caudal tufts.

"Wings rather narrow, smoky along the costal area; basal cross-vein oblique, joining the fourth vein beyond the anterior cross-vein; costal vein blue and purple scaled. Halteres with pale stems and black silver scaled knobs.

"Legs slender; vestiture deep violet and blue marked with white; femora pale at base, bright brassy beneath and at sides, apex dark ringed; knees white; front tibiae brassy on outer side; middle tibiae brassy on inner side; hind tibiae with golden scales on outer side; front and middle tarsi with second and third and all but apex of fourth segments brilliant white; hind tarsi with extreme apex of third, all of fourth, and all but the tip of fifth segments brilliant white. Claw formula, 0.0–0.0–0.0.

"Length: Body 7 to 10 mm.; wing 6 to 7.5 mm.

"*Larva, Stage IV.* Head subquadrate, longer than wide, sides nearly straight, insertion of antennae rather prominent; front margin deeply emarginate at middle, produced on each side of it into a large prominent lobe. Antennae cylindrical, slender, rather long, smooth; two separate hairs at outer third, followed by a short multiple tuft; three small terminal digits and a long seta. Two pairs of single hairs behind frontal-lobes, a group of three in the sinus behind antennae, some small tufts beyond middle of sides. Mouth brushes inserted on frontal lobes, folded downward and backward, composed of ten stout, curved, lamelliform blades with slightly hooked cleft tips. Mental plate broadly triangular, emarginate at apex for the space of the three middle teeth, seven teeth on each side, stout, subequal; secondary plates thin, membranous, with apical fringes. Mandible quadrangular, straight without, smooth; two branched appendages at angle before tip; an outer row of coarse cilia; terminal dentition of five teeth, very large, ensiform, the third and fifth smaller; a large rounded projection based of teeth, within which arises a row of long subequal setae. Maxilla rounded quadrangular, basal angle with a group of flattened appendages with recurved tips; inner angle with shorter filaments, a seta, and two papillae; palpus nearly divided by the suture, erect, columnar, flat at tip, smooth, with three rudimentary terminal digits. Thorax rounded, about as wide as long; lateral hairs short, very stout, heaviest ones spinulose. Abdomen stout, segments angled at sides, anterior ones shorter; hairs abundant but not long, all the lateral tufts coarse, multiple to fifth segment, arising from large chitinous tubercles. Tracheal tubes moderately broad, invisible in the larva, the skin darkly pigmented. Air-tube stout, conically tapered outwardly, about two and one-half times as long as wide; no pecten; a single tuft near base. A large plate on sides of eighth segment with two stout spinulose hairs on its posterior margin. Anal segment about as long as wide, ringed by the plate; dorsal tufts of two long brushes on each side; a single spinulose lateral hair; ventral brush well developed, of branched tufts, posterior one feathered; anal gills very short, bud-shaped.

HABITS

"The larvae live normally in water in hollow trees where other mosquito larvae occur upon which they feed. More rarely they are found in artificial receptacles. Specimens have been taken in water-filled rock holes in which cases they were associated with *Aëdes atropalpus*. The eggs are found floating on the water singly and the larvae hatch quickly. They feed exclusively upon other mosquito larvae present, which they swallow whole. They feed largely upon *Orthopodomyia signifer* and *Aëdes triseriatus* but will also eat other larvae when opportunity offers, even of their own species. Hibernation occurs as fully grown larva and pupation follows in the spring, as shown by Morgan and Cotton. There are probably several generations during the season, as the imagos occur from early spring until late in the autumn. The larvae can only overwinter in tree-holes containing permanently a supply of water. The adults are diurnal, both sexes frequenting flowers. Mr. Thibault has made the following observations which seem to stand

PLATE XIII. TOP. Newark Schools Stadium where 20,000 people were protected during an evening concert. The area is being fogged by New Jersey larvicide distributed by high pressure power sprayer. BOTTOM. During the intermission, which occurred just before the evening flight of mosquitoes, the area was again fogged to insure the continuance of the protection.

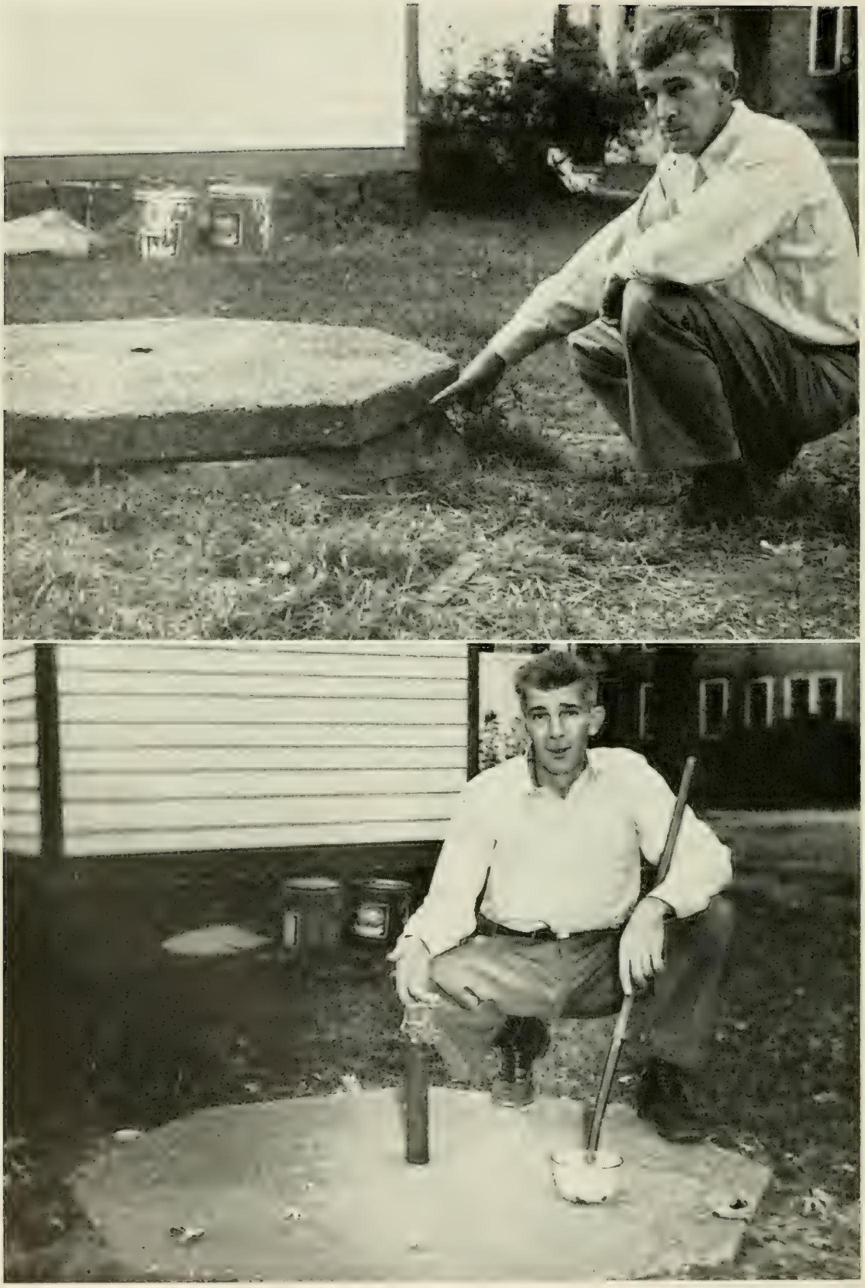


PLATE XIV. TOP. Mosquitoes breeding in the cesspool have an easy escape through the crack below the concrete slab and through the vent hole in the center of the slab. BOTTOM. The same cesspool now has been made mosquito-proof. Earth seals the crack under the concrete slab, and a screened vent pipe has been installed.

in relation to the mating habits: 'I find the males of a certain locality all go to some certain tree or bush and are always to be found there, yet not a single female will be seen. I have looked at all times of the day and before day and after night. I took all my males (a hundred or so) on some poison ivy that grew on a hackberry tree 100 yards from the breeding log. I could always find them here after they just made their appearance and nowhere else. The most of them were taken from the same bunch of leaves; but not a female did I ever see.' "

Other Species

In addition to the thirty-seven species described above four more have been identified in this state. They are rare and of no great economic importance, but should be listed here. *Mosquito News*, Volume 2, Number 4, describes the last three species listed here.

Aëdes fitchii Felt and Young was first listed by Dr. Smith in his mosquito report of 1906.

Aëdes mitchellae Dyar has been recognized by several members of the staff of the Entomology Department of the New Jersey Agricultural Experiment Station. It was first taken in a trap by Mr. Fred A. Reiley in 1941. In 1942 Mr. Thomas D. Mulhern collected a pupa near New Egypt, and the adult reared was determined by Dr. Alan Stone. Since then many *A. mitchellae* larvae have been collected throughout the state.

Anopheles atropos Dyar and Knab is recorded by Dr. T. C. Nelson in the twenty-ninth *Proceedings New Jersey Mosquito Extermination Association.*

Theobaldia inornata Will. was found by Mr. Flynn in Passaic County in 1941, and by Mr. Reiley at Port Republic in 1942.

5

INFLUENCE OF ENVIRONMENT

TEMPERATURE

TEMPERATURE, as shown in the preceding chapter, probably affects mosquito life more widely than anything else. The mosquito is a cold blooded animal and its body temperature is usually only a few degrees higher than the temperature of the surrounding medium. The temperature of the medium surrounding the insect determines the rate of its metabolism, may destroy it by freezing or may kill it by heating.

Field observations of the behavior of *Aëdes sollicitans* and *Aëdes cantator* adults, as reported by Rudolfs in Bulletin 388, *N. J. Agricultural Experiment Station,* showed that a temperature between 68°F. and 77°F. had the greatest accelerating influence upon the rate of their activities. The author has observed that adult activity is very slight when the temperature falls to 60°F. and virtually ceases at 40°F. Death follows formation of ice within the body, but does not occur above 30°F. and usually only at lower temperatures.

Experiments conducted by the author in 1940 and 1941 with larvae of *Culex pipiens* and *Aëdes aegypti* showed that metabolic activity of the larvae was greatest between 68°F. and 87°F. As temperatures rose above 90°F., activity slowed down. Death occurred within a few days at temperatures of 102°F. and over.

Mosquito species passing the winter as adults in the latitude and elevation of New Jersey are nearly always so reduced in numbers that they cannot reach large numbers before midsummer. Mosquito species passing the winter as eggs can and usually do produce large broods prior to midsummer. As study of the 1933 trap collections will show, *Culex pipiens,* which passes the winter as an adult, is the dominant species, but these records show that this position of dominance is not reached until July. On the other hand *Aëdes canadensis* and *Aëdes vexans,* both of which pass the winter as an egg, are abundant prior to July. Once each year, during the winter, the mosquito fauna is greatly reduced in number by low temperature and must make a new start the following spring.

Larval development during the spring is so slow that a species requiring seven to eight days in midsummer will not complete its larval stage under four to nine weeks. Mosquito larvae of the species wintering in the larval form are readily resistant to ice-forming temperature. Indeed, they may be frozen in the ice and still live after the ice enclosing them is melted. These larvae do not really freeze, because the concentration of the body water depresses the freezing point. If the body water really freezes the insect dies.

WATER

Natural water, adequately charged with food materials, is probably next to temperature the most important factor. Acidity of natural waters appears to be a relatively unimportant factor because successful breeding occurs in water well above neutrality (alkaline) to as far below as pH 4.0. It is, however, possible to have such a concentration of dissolved salts that mosquito larvae will die. Such cases are exemplified by the clay pits where dissolved aluminum is probably the toxic agent and by highly evaporated salt marsh pools in which salinity (salinometer reading) reaches twenty-two per cent or above.

Sea salt concentration appears to prevent the fresh water mosquitoes from breeding on the salt marsh. Salt marshes from which salt water has been long excluded show breeding of such fresh water species as *Aëdes vexans*. It appears also to govern the development of wrigglers of certain salt marsh mosquitoes. In the spring the dominant mosquito emerging from the salt marsh is *Aëdes cantator;* later it is *Aëdes sollicitans. Aëdes cantator* emergences are normal throughout the season from brackish marshes along the higher courses of the rivers. The same salt marsh pool which turns out *Aëdes cantator* in the spring may turn out *Aëdes sollicitans* later. In view of the fact that these species pass the winter as eggs in the marsh mud, it seems likely that low salinities encourage the hatching and larval growth of *Aëdes cantator*, discourage hatching and growth of *Aëdes sollicitans*, while high salinities encourage the hatching and larval development of *Aëdes sollicitans* and discourage the hatching and growth of *Aëdes cantator.*

To be successful breeders of mosquitoes, natural waters must not only have adequate food supply but they must remain long enough for the larval and pupal stages to be completed. In midsummer, under high temperatures, species that complete the pupal stages quickly, such as *Aëdes sollicitans*, may complete pupal stages in the wet mud of drying pools.

There is no doubt that species of mosquitoes show greater success during seasons of heavy and well distributed rainfall, because that type of rainfall not only creates an enormous increase in number and size of pools but maintains them over a period sufficiently long to permit the completion of brood developments.

The persistence of temporary breeding pools over sufficiently long periods to permit completion of the mosquito life cycle is dependent not alone upon rainfall, but also upon rate of evaporation. The two factors —rainfall and evaporation—so completely underlie favorable or unfavorable mosquito-breeding conditions that we can say that when the weekly rainfall curve rises high above or falls below or scarcely above the weekly evaporation curve the season will show many mosquitoes or few mosquitoes. This conclusion applies to natural waters on the upland and only to a less extent on the salt marsh. It does not apply to sewage-charged permanent waters or diked and drained salt marsh. The seasonal distribution of relative rainfall and evaporation is an important factor.

Newly emerged mosquitoes, as has been noted in the last chapter, get on the wing beginning in May and continue well into September, a period of about five months. For the sake of studying rainfall effects it is best to divide this period in three parts, each including fifty-one days. The forepart of the mosquito season would thus run from May 1 to June 20, the middle from June 21 to August 9, and the latter from August 10 to September 29. The period required for mosquito development in midsummer is covered by a ten-day period. It has been found best to aggregate the rainfall and evaporation data in ten-day periods and for comparison purposes to strike curves on that basis.

When the evaporation curve is as high or higher than the rainfall curve, the period covered by this condition is said to be *dry*. When, however, the evaporation curve is much lower than the rainfall curve the period is said to be *wet*:

TABLE II

Fore Part of Season	Middle Part of Season	Latter Part of Season	Mosquito Prevalence	Dominant Species
Dry	Dry	Dry	Few mosquitoes	*vexans, pipiens*
Dry	Dry	Wet	More but still few	*pipiens*
Wet	Dry	Dry	More but still few	*vexans, canadensis*
Dry	Wet	Dry	More but still few	*vexans, pipiens*
Wet	Dry	Wet	More but still few	*vexans, pipiens*
Wet	Wet	Dry	More but still few	Few *vexans* and many *pipiens*
Wet	Wet	Wet	Great abundance of all species	*vexans, canadensis, pipiens,* and *territans*

Rainfall has an effect on salt marsh breeding similar to that which has just been described for the upland breeding species, but the dominant water factor is the tide. The average elevation of the salt marshes when in contact with salt marsh creeks is about 2.3 feet above mean tide at Sandy Hook. Of course, from this elevation the marshes slope gradually downward as they approach the highland, reaching their lowest point at the line of junction. Tides higher than normal are required to cause water to flow over them. Tides sufficiently high for this purpose come once each month. High tides also occur as the result of strong favoring winds.

Tides high enough to cover the grasses initiate mosquitoes but bring killifish in to destroy the wrigglers. Tides not high enough to cover the grass will water soak the marsh, but will not bring in the killifish because the grass stems keep them back. If the water from the latter type, which is sometimes called a "trickle tide," remains long enough to permit the brood of mosquitoes to complete development and emerge, it is the greatest contributor to mosquito prevalence. Dry weather will often dry up the pools left by such a tide before wrigglers can produce mosquitoes, or wet weaather by preventing evaporation may favor emergence of large broods.

FOOD SUPPLY

Since accurate data on the food of mosquito larvae is rather scarce and since this question is highly important in the practical work of mosquito control, contributions made by Rudolfs (21, 22) in 1925 and 1926 are reproduced:

"Last summer a number of samples were collected from places where permanent and temporary mosquito-breeding occurred. Duplicate samples of water were taken, one with, and another without mosquito larvae. The water was analyzed and microscopically examined for plant and animal life (10). The mosquito larvae were dissected and their intestines examined. Of the approximately fifty samples a few analyses and results of examination are here given as typical cases. These examples are presented as a preliminary work.

"A short description of the places where the samples were collected will give some idea of the environment of the breeding places.

"Number 38. A ditch, about five feet wide and three to four feet deep, stagnant water, with some scum on top. Ditch highly polluted by drainage from workingmen's houses in neighborhood. Prolific breeding of *Culex pipiens*.

"Number 39. A small pool in several acres of woodland. Many similar pools present. Growth: oaks, ash, etc., with heavy undergrowth. Pool choked with vegetation, thick brown scum on top, water beneath scum clear. *Aëdes vexans* breeding.

"Number 41. A small brooklet overflowing with surface drainage water, causing temporary pools. Water stagnant in small patch of woods, mostly oaks. Fairly heavy breeding of *Culex pipiens* and *Aëdes canadensis.*

"Number 43. A permanent pool on Galloping Hill Road in Borough of Kenilworth. According to Mr. Russell W. Gies, superintendent of the Union County Mosquito Commission, no breeding was reported from this pool for several years. The pool was shaded by red and pin oaks on one side. There were water lilies in the middle of the pool, also some grass, and the pool was bordered by grass, weeds, and shrubbery, with some dead tree trunks on the edge.

"Number 44. A permanent drainage ditch which forms a small lake during heavy rains on other side of the road from sample 43 was reported to have bred nothing but *Aëdes vexans.* There was sparse breeding, at the time the sample was taken, of *Psorophora ferox* Humb.

"The microscopic plants and animals present in the water, together with a description of material found in the intestinal tract of the larvae are given in Table III. The samples taken in these places showed (a) *Culex pipiens*, (b) *Aëdes vexans*, (c) *Culex pipiens* and *Aëdes canadensis* breeding together, (d) *Psorophora ferox*, and (e) a place where apparently no breeding occurred for several years. A perusal of the table shows that plenty of food was present in all these samples. In the instance where *Culex pipiens* and *Aëdes canadensis* were breeding together some 60,000 minute flagellates per cubic centimeter occurred in addition to four other protozoa and species of microscopic plants. In the case where *P. posticata* larvae are present no plant life was found, but there occurred five protozoan species, of which one (*Euglena mutabilis*) was present in very large numbers (270,000/cc.). In all samples minute flagellates were found except where *P. ferox* was breeding; for the remainder certain organisms occurred in several places while not in others.

"An examination of the intestinal tract of the larvae seems to show that species of *Euglena* are among the favored food. The guts of *C. pipiens* were crammed with *Euglena polymorpha*, while large numbers of *Euglena mutabilis* were found in the tracts of *P. ferox*. Abundant diatoms found in larvae from sample 41 were mostly empty shells; some did not seem to be harmed. *Trachelomonas* were present in various stages of digestion, but in some cases the animals were alive and moving.

The intestines were filled with brown desiccated matter from the bottom of the pond. Both young and old larvae had about the same sort of intestinal contents, and the evidence seems to be that food is taken at random. If undisturbed the larvae would constantly move their mouth parts, creating a current in the water. The operation is continuous except when some large particle is seized, when the movement of the mouth parts is stopped long enough for the particle to be chewed and swallowed or else cast aside. It seems therefore that food is taken as it passes the mouth at random; that part which can be crushed is crushed, but small cysts are apt to pass through unharmed. The latter might happen with small flagellates and diatoms if the available food is abundant, otherwise the protoplasm is simply digested out of the shells of the diatoms and the small flagellates digested beyond recognition.

"It is conceivable that the kind of organisms present in the water is dependent upon the chemical constitution of the water. A comparison of chemical analyses of the different samples (Table IV) shows that in the water where *C. pipiens* were breeding 219 parts per million of CO_3 as $CaCO_3$ and ninety-one parts per million of Cl were present, while in the sample where *C. pipiens* and *A. canadensis* larvae had their habitat, practically no Cl or CO_3 was found. However, the former was distinctly alkaline (pH 7.5) and the latter distinctly acid (pH 6.1). In the latter case the water was collected from a small brooklet in a small patch of woods, and plenty of decaying leaves and small branches of the oak trees standing thereby had dropped in the brooklet. The water was colored, indicating possible presence of tannins, but unfortunately no test for tannin was made at the time.

"In the case where *A. vexans* was breeding, 132 parts per million of CO_3, with no Cl, was present, the sample being distinctly alkaline (pH 8.0). In the water where *P. ferox* was found appreciable amounts of Al, Fe, SO_4 were present; also some Cl. The SO_4 amounted to more than 0.25 per cent. Nearly all the iron present was in the ferrous state. The water was yellow, and although no sediment was present, the guts of the larvae contained large quantities of ferric hydroxide. It is very likely that the soluble iron was precipitated by the fluids secreted from the larval bodies into their guts. The remarkable thing was that these larvae were able to live and survive in this strongly acid water. The total acidity found by titration was 836 parts per million, and the hydrogen-ion concentration proved to be pH 2.9.

"In the pool from which no breeding has been reported for several years the food supply was plentiful, and nothing indicates from the chemical analyses why no breeding should occur.

TABLE III

Animal and Plant Life Found in Water and in the Intestinal Tract of Mosquito Larvae

	Water					Intestinal Tract	
	Plants Species	No. per cc.	Animals Species	No. per cc.	Name of Larvae	Plants	Animals
38	Diatoms	2100	Euglena polymorpha	2400	Culex pipiens	Few diatoms	Guts crammed with
	Oscillatoria	2100	Vorticella	300		Oscillatoria	Euglena polymorpha; Opercularia
			Oxytricha				present
			Amoeba				
			Cyclidium				
			Minute flagellates				
39	Oscillatoria		Minute flagellates		Aedes vexans	Oscillatoria	Vorticella
			Vorticella				Small flagellates
			Cyclidium				Brown debris
41	Diatoms	1200	Minute flagellates	60000	Culex pipiens	Diatoms	Encysted Euglena
	Tribonema		Trachelomonas	600	and	Tribonema (small	Trachelomonas
			Euglena	300	Aedes canadensis	pieces, partly	Arcella
						digested)	
	Gonium		Amoeba			Gonium	Much brown debris
			Metozoa				
			Rotifers				
			Watermites				
			Cyclops				
43	Diatoms	300	Minute flagellates	6600	No breeding		
	Stichococcus		Cyclidium	300			
			Arcella				

		Halteria Vorticella Carchesium Rhipidodendron Euglena				
44	No plant life	Euglena mutabilis Actinophrys Arcella Uroleptus Cyclidium (The Euglena formed a greenish scum on top of the water, but a mixed sample was obtained and stirred.)	270000	Psorophora ferox	No plants	Euglena mutabilis (large numbers; all apparently dead and decomposing) Much brown debris, resembling ferric hydroxide Many soil particles

TABLE IV

Chemical Analyses of Waters

No.	Ca Mg.	Al	Fe	CO_2	CO_3	SO_4	Cl	Total Solids	Volatile Matter	pH	Color **
	per cent	per cent	per cent	p.p.m.	p.p.m.	per cent	p.p.m.	per cent	per cent		
38	0.018	0.00	Trace	0.4	219	Trace	91	0.024	0.016	7.5	0
39	0.009	0.00	0.00	0.0	132	0.000	0	0.018	0.010	8.0	0
41	0.000	0.00	Trace	0.2	1	0.016	0	0.016	0.014	6.1	1
43	0.000	Trace	Trace	0.4	16	Trace		0.090	0.086	6.3	2
44	0.000	0.99	*.085		0	0.256	65			2.9	10

* Fe nearly all in ferrous state.
** Color, yellow. Highest score is 10.

TABLE VI

Analyses of Water from Typical Woodland Pool, Passaic County (1925)

No.	Date	pH	Res. pH	CO_2	CO_3	Cl	SO_4	Color †	Name of Larvae	No. Larvae
1	3/16	4.8	5.0	13.2	5.3	5.9	67.4	6	*	0
5	3/19	5.1	5.2	3.5	3.3	9.9	26.3	2	A. canadensis	7
12	3/31	5.5	5.6	4.4	6.0	4.9	29.6	4	A. canadensis	7
23	4/16	4.9	5.0	4.4	2.6	5.9	26.0	6	A. canadensis	7
30	4/29	4.6	4.8	11.4	2.4	5.9	65.7	3	A. canadensis	20
35	5/14	4.8	5.0	6.1	2.4	9.9	16.4	6	A. canadensis	24
41	5/28	4.6	4.8	9.6	3.6	7.9	65.7	3	A. canadensis	**
47	6/11	5.4	5.8	13.0	4.8	39.7	76.9	3	A. canadensis	0
	6/18	Pool dry								
63	8/11	4.9	5.4	18.4	6.0	8.0	44.5	2	A. canadensis	20

† Highest score — 10.
* Breeding reported on March 6; no larvae found on March 16.
** In 20 dips 6 larvae and 1 pupa (dipper holding about 200 cc.).

"The studies on food for larvae were continued in 1925. A number of sampling places were selected and water taken from these places at regular intervals of fourteen days. The work was started in the middle of March and terminated in several cases at the end of the first week of October. The samples were analyzed chemically and microscopic determinations made of the life they contained. The data in hand is quite voluminous and only a small part can here be presented. For discussion I have selected two places, namely one typical woodland pool where continuous breeding of *Aëdes canadensis* occurred and another where supposedly no breeding would take place.

"The first place was located about 200 feet from a highway (Union Avenue) in Passaic County and was surrounded by white maple, red maple, oak, a few birch and beech trees, some brush, and a dense growth of cinnamon ferns. At the bottom of the pool was a mat of decaying leaves. It was irregular in shape, fairly shallow, ranging from twelve to eighteen inches deep, and about seventy feet long by forty feet wide. At the end of May about ninety-five per cent of the pool was shaded at noon time, while at other times of the day the water surface was even less exposed to the sun.

"The second place, located in Union County, like number 43 along Galloping Hill Road, had not bred mosquitoes for several years. This pool was practically round, fifty feet in diameter, and from three to five feet deep. It was shaded by red oaks and pin oaks on three sides, but in the afternoon was exposed to the sun. In July the edges of the pond were covered with duck weed and it was about half filled with water lilies. There was some surface drainage from the concrete road. At the end of July some old iron and tin cans were noticed, in addition to the dead wood earlier present.

"Tables V and VI show the results for the Passaic County pool. It will be noticed that the food supply was abundant throughout the summer. The water remained acid with some variations. Chlorides were low, except in the middle of June when the water became low. At this time larvae disappeared entirely. After the pool had been dry for six weeks, heavy rains brought back water and a few days later breeding was very heavy again. However, the water disappeared rapidly and no water was reported for the remainder of the season. Our samples were taken in duplicate, one for microscopic and chemical examination, the other for larvae. Early in the season an attempt was made to find out what the larvae eat by examining the water in both bottles, but this might be considered as not being representative, since they would possibly take anything they could get in such a relatively small amount of water.

TABLE V

Microscopic Plants and Animals Present in Water from a Typical Woodland Pool in Passaic County (1925)

1925	No.	Plants and Animals		
Date		Plants	Protozoa	Remarks
3/16	1	Diatoms Fungi	Amphisia Oicomonas Trachelomonas Chilomonas Euglena sp. (Gymnodium) * No. of dinoflagellates Small flagellates (Nematodes — few) (Hydracarinae) (Cyclops)	Life not teeming, but fairly abundant
3/19	5	Few fungi Few diatoms	Small flagellates (Cyclops) (Hydracarinae)	Heavily infested with cyclops and the minute crustacea
3/31	12		Dinoflagellates Euglena Small flagellates Trachelomonas Uroleptus Amphisia (Rotifers) (Hydracarinae)	Enough food, could feed many wrigglers
4/16	23	Algal spores Diatoms Fungi	Trachelomonas Heleopera Minute flagellates Euglypha Diffugia Trinema Chlamydomonas Euglena Oxytricha Aspidisca Chilomonas Synura (Hydracarinae) (Nauplius of Cyclops) (Unknown Rotifers)	Algal spores most numerous, but many Chilomonas, Trachelomonas, etc. It is noteworthy that most of these had disappeared in the bottles containing larvae

1925		Plants and Animals		
Date	No.	Plants	Protozoa	Remarks
4/29	30	Diatoms Algal spores	Minute flagellates Trachelomonas Arcella Aspidisca Euglena viridis Difflugia (Rotifers)	Food not abundant, although the flagellates and algal spores were very numerous — likewise, *Trachelomonas.* Remains of cyclops
5/14	35		Carchesium Minute flagellates Euglena Vorticella Trachelomonas	
			Dileptus Arcella Difflugia Aspidisca Halteria (Cyclops) (Rotifers) (Small turbellarian related to Microstomum)	Enough minute flagellates to feed larvae
5/28	41		Trachelomonas Menoidium (?) Chilomonas Minute flagellates Prorodon Vorticella Arcella Frontonia Euglypha Mallomonas Cyclidium Aspidisca (Rotifers) (Cyclops)	Enough of the first three protozoa for food. Little debris
6/11	47		Chilomonas Minute flagellates Chlamydomonas Peranema Aspidisca Vorticella Chilodon (many cyclops)	Easily enough protozoa for food

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* In parentheses organisms other than protozoa.

Examination of the gut contents of larvae, brought into the laboratory directly from the pools, gave some interesting indications of what they really lived on. Results of a few examinations will suffice as examples.

"Number 23. Gut contents of two larvae. Protozoa: *Euglypha, Trinema, Trachelomonas, Arcella, Chlamydomonas, Euglena.* Plants: Fungus spores, zygospores of an alga, a few diatoms; there was also a cyst of what was probably a ciliate. Most of the food, however, was *Trachelomonas* and the algal spore. No oil was present in the gut and but little in the larvae.

"Number 20. The gut contents of two larvae showed that they had eaten heavily of *Daphnia*, which were numerous in the water, but had, perhaps, eaten the dead and disintegrating Copepods, for the living ones were clearly too large for a mouthful. The gut contents showed also some black mud and huge quantities of a well digested alga, apparently *Tribonema.* Some few diatoms and specimens of *Phacus*, along with an organism somewhat like *Chlamydomonas*, completed the menu. Not many protozoa were present in the water in which these larvae lived.

"Number 32. These larvae had practically nothing in their intestines but *Trachelomonas*, which organism was most abundant in the water.

"These examples show that the larvae (all *A. canadensis*) lived on the animals and plants as they occurred in the water. In the case of Number 23 the diet was mixed, including protozoa and algae; in the case of Number 20, they fed mostly on algae, whereas in the case of Number 32 practically nothing but a protozoa was devoured.

"We notice from Tables VII and VIII that, in the pool in Union County, where no breeding was expected, during the middle of March enough food was present to support larvae for a short time. This food supply decreased until, in the beginning of August, the water was almost sterile. Up to this time, some larvae of a little fly, *Corethra sp.*, were found. In the second part of August the food supply increased somewhat and the larvae of a non-biting mosquito, *Uranotaenia sapphirina*, were found. These occurred when the chloride content decreased markedly. They disappeared again, coinciding with a considerable increase of chloride and sulfate content, due apparently to rains causing street washings from the concrete road to flow into the pond. On September 15, when the chloride content was lowest and the food supply had increased, larvae of *C. pipiens* and *Anopheles* species were taken. The week in September, when chlorides had increased again but all sulfates disappeared, larvae were still present. During the entire season sulfates were comparatively high in this water. Every time, when these comparatively large quantities of sulfates were present, a strong

TABLE VII

Microscopic Plants and Animals Found in Water from Pool in Union County (1925)

1925		Plants and Animals		
Date	No.	Plants	Protozoa	Remarks
3/17	3		Euglena acus Trachelomonas volacina Small green flagellates (Rotifers) *	Enough food for short time, up to 50,000 per cc. of organisms
3/31	9	Algal spores of Dinobryon	Small flagellates Euglena acus Trachelomonas Synura Amoeba Dinoflagellates	Life fairly abundant
4/14	21	Diatoms Tribonema	Minute flagellates Synura Euglena Dinoflagellates Chloromonas	Very little life — not sufficient apparently for larvae
4/28	26	Diatoms	Minute flagellates Colpoda Vorticella Euglena	Hardly sufficient food supply
5/12	33	Minute unicellular Alga Diatoms	Minute flagellates Trachelomonas Euglena Heteronema	Enough food
5/26	39	Diatoms	Oxytricha Minute flagellates Trachelomonas Euglena	Not enough food
6/9	46		Diatoms and green algae Small flagellates Trachelomonas (Large numbers of cyclops)	Not enough food
6/23	50	Closterium Diatoms	Minute flagellates Trachelomonas (Cyclops)	Very little life

1925		Plants and Animals		
Date	No.	Plants	Protozoa	Remarks
7/7	53	Diatoms	Minute flagellates Two small flagellates Oxytricha Arcella (Daphnia)	Very little life, little debris
7/21	58	Diatoms, few	Rhipidodendron Minute flagellates Trachelomonas Aspidisca (Cladocera)	Little life
4/8	62	Diatoms Desmids	Few minute flagellates (Cyclops) (Ostracoda)	Water almost sterile; little debris
8/18	65	Diatoms Oxcillatoria	Arcella Amoeba verrucosa Minute flagellates Pelalomonas Chlamydomonas Carteria Euglena	Life fairly abundant
9/1	69	Diatoms	Arcella Minute flagellates Trachelomonas Small ciliates	Little detritus Remains of numerous Cladocera (water yellow)
9/15	72	Diatoms	Amoebae Arcella Trachelomonas Minute flagellates Aspidisca (Tardigrade) (Copepods, few)	Little debris
10/6	75	Diatoms	Vorticella Minute flagellates Amoebae	Very little debris

* In parentheses organisms other than protozoa.

smell of hydrogen sulfide was noticeable, indicating sulfate reduction by bacterial action. It has been stated by some investigators that H_2S is very toxic to larvae but we know that this does not always hold for salt water species. Frequently I have taken larvae from ditches emanating a strong odor of H_2S and I have no doubt that the inspectors have

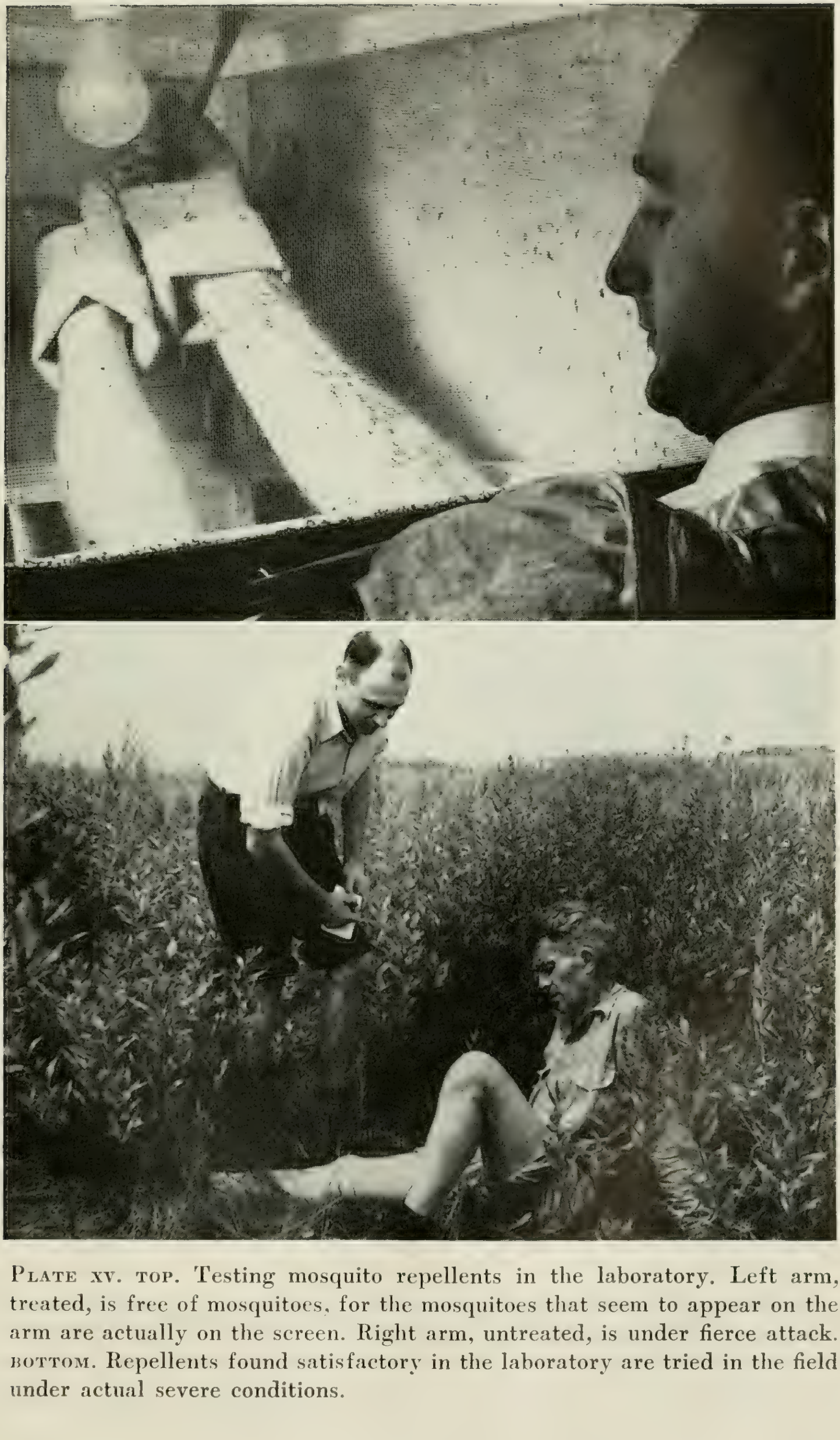

PLATE XV. TOP. Testing mosquito repellents in the laboratory. Left arm, treated, is free of mosquitoes, for the mosquitoes that seem to appear on the arm are actually on the screen. Right arm, untreated, is under fierce attack. BOTTOM. Repellents found satisfactory in the laboratory are tried in the field under actual severe conditions.

PLATE XVI. TOP. Members and guests of the Conference Committee on Mosquito Extermination inspecting Newark meadows, then recently ditched, on June 2, 1905. In the foreground, in cap, is Dr. John B. Smith. BOTTOM. Associated Executives of Mosquito Control Work in New Jersey. This organization has met monthly since 1921. Seated at head of table is Thomas J. Headlee.

done the same. It is well known that poisons applied in small quantities act as stimulants. Two years ago I successfully used bacterial cultures producing H_2S as an attractive agent for mosquitoes.

TABLE VIII

Analyses of Water from Pool in Union County (1925)

No.	Date	pH	CO_2	CO_3	Cl	SO_4	Color †	Name of Larvae	No. Larvae
3	3/17	4.9	3.5	5.3	9.9	80.5	2		0
9	3/31	6.9	.8	27.7	11.7	158.8 *	1		0
21	4/14	6.7	.4	7.9	9.9	64.1	0	Corethra spec.	4
26	4/28	5.7	2.6	7.2	11.9	65.7	1	Corethra spec.	6
33	5/12	5.8	1.1	7.2	15.8	57.5	2		0
39	5/26	6.5	2.6	6.0	6.9	34.5	1		0
46	6/9	6.6	2.6	22.8	17.8	49.3	2		0
50	6/23	6.4	2.6	27.6	7.8	175.9 *	2	Corethra spec.	1
53	7/7	6.6	2.8	18.0	10.0	24.6	2	Corethra spec.	9
58	7/23	6.4	1.7	14.4	12.0	32.9	1		0
62	8/4	6.2	3.5	10.8	10.0	74.0	1		0
65	8/18	6.2	5.0	12.5	2.0	85.6	3	Uranotaenia sapphirina	15
69	9/1	6.7	3.6	18.0	8.5	171.0 *	5		0
72	9/15	6.7	5.0	18.0	0.8	66.0	1	C. pipiens and Anopheles spec.**	15
75	10/6	6.7	3.5	12.4	10.9	0	1		7

† Highest score — 10.
* Strong smell of hydrogen sulfide.
** Two Anopheles larvae died before full grown.

"At the time when the *Culex* and *Anopheles* larvae were taken in the pond, no determinations of ammonia and albuminoid nitrogen were made, but the sample taken before showed 0.4 ppm., NH_3-N and 4.1 ppm. albuminoid-N, while the sample taken after, when larvae were still present, contained 0.5 ppm. NH_3-N and 4.3 ppm. albuminoid-N. The albuminoid-N tends to show a slight pollution, probably from street washings. The data presented seems to indicate that our conclusion reached formerly (20) was correct, namely that food supply for larvae is the main cause governing breeding. This food supply in turn is dependent on the chemical composition of the water. Atkins (1), in studying the phosphate content of the water in relation to the growth of algal plankton, shows that phosphate is the limiting factor for the growth of diatoms. Atkins and Harris (2) found that an accumulation of phosphate results in a tremendous increase of phytoplankton. These results seem to support our statement, at least as far as algae are concerned, that food supply is determined by the chemical composition of the water. Since it seems fairly clear that mosquito larvae will eat what they can get and the choice of breeding place might depend on the type of food present, we must know from the chemist and specialized biologist which chemical factor or factors determine sufficient food supply, why it is that sometimes only a certain type of growth occurs, or what causes partial sterility of the water. After we know something about these things, a modification of factors governing food supply might then be comparatively easy and the road is open for a different type of mosquito control."

NATURAL ENEMIES

Birds, bats, and dragon flies eat adult mosquitoes. Dragon fly nymphs and predaceous diving beetle larvae feed on the wrigglers, certain tadpoles and salamanders destroy mosquito larvae. Certain "hair snakes" and mites are known to parasitize mosquitoes.

All these enemies, however, are of small importance in comparison with the killifish which live in creeks, ditches, and pools of salt marshes and are the great natural enemies of salt marsh mosquito larvae. No adult mosquitoes emerge from waters containing them.

The following list covers some of the recognized natural enemies of mosquitoes:

INVERTEBRATES

Protozoa—*Spirochaeta culicis, Diplocystis, Nosema stegomyiae, Crithidia fasciculata, Herpetomonous algeriense, Trypanosoma culicis.*

Coelenterata—*Hydra fusca, Hydra viridis.*

Platyhelminthes—*Agamodistomum martiranoi.*

Nemathelminthes—*Agamomermis culicis.*

Arthropoda—*Hydrophilus obtusatus, Dytiscus marginalis, Acilus sulcatus, Nepa, Notonecta, Ranatra fusca, Aeschna, Erythemis simplicicollis, Psorophora ciliata, Megarhinus septentrionalis, Lutzia bigotii, Lesticocampa, Corethra, Tanypus dyari, Lispa sinensis, Horpopeza obliterate, Tahydromia macula, Cordilura haemorhoidalis, Monedula signata, Emesa longipes, Salticus, Crangon vulgaris.*

VERTEBRATES

Pisces—*Fundulus heteroclitus, F. majalis, F. diaphanus, Gambusia affinis, Cyprinodon variegatus, C. calaritanus, Heterandria, Ambramis chrysolencas, Carassius auratus, Eupomotis gibbosus, Mollienisia* *latipennis*, *Girardinus poeciloides*, *G. caudimaculatus*, *Haptochilus*, *Esox lucius*, *Lucania parvia.*

Amphibia—*Rana pipiens*, *R. palustris*, *Discoglossus pictus*, *Triton cristatus*, *T. alpestris*, *Diemyctylus torosus*, *Amblystoma opacum.*

Aves—

Chordeiles minor (Forster). Eastern Nighthawk.
Chaetura pelagica (Linnaeus). Chimney Swift.
Iridoprocne bicolor (Vieillot). Tree Swallow.
Hirundo erythrogaster (Boddaert). Barn Swallow.
Petrocehlidon albifrons (Rafinesque). Cliff Swallow.
Progne subis (Linnaeus). Purple Martin.
Riparia riparia (Linnaeus). Bank Swallow.
Myochanes virens (Linnaeus). Eastern Wood Pewee.
Sayornis phoebe (Latham). Eastern Phoebe.
Lyrannus tyrannus (Linnaeus). Kingbird.
Avas plalyrchynochos (Linnaeus). Common Mallard.

Mammalia—Bats, Man.

Five species of killifish are recognized on the New Jersey marshes:

THE STRIPED KILLIFISH (*Fundulus majalis* Walbaum), which may be distinguished by the markings shown in Fig. LXXVII, reaches a length of six to eight inches. It occurs throughout the Jersey coast, enters with the tide and goes out with it. It is useful, but less valuable for mosquito control than the following species:

THE COMMON KILLIFISH, otherwise known as the "mud-fish," "mud-dabbler," "mummichog," and "salt water minnow" (*Fundulus hetoroclitus macrolepidatus* Walbaum), is perhaps more effective than any other fish as a salt marsh mosquito larvae destroyer. The females are nearly uniformly olivaceous, but lighter below. The males are dark greenish, with many narrow, irregular, silvery bars on the sides; the belly is yellowish or orange; the sides more or less spotted with white or yellow. This species reaches a length of four and one-half inches and occurs throughout the New Jersey salt marsh. Mr. Seal (23) has the following to say about it: "This species is abundant everywhere to the extreme limits of tide water. They are equally at home in salt or fresh water, the clearest water or the muddiest pool or ditch. They are not even averse to filthy sewage water, collecting in vast numbers at the mouths of sewers at low tide. They will be found in the most insignificant and shallowest depressions on the flats or marshes, in ditches filled with reeds, spatterdocks or masses of submerged plants, and in muddy holes devoid of plants or other shelter. They will push through places where there is hardly enough water to cover them."

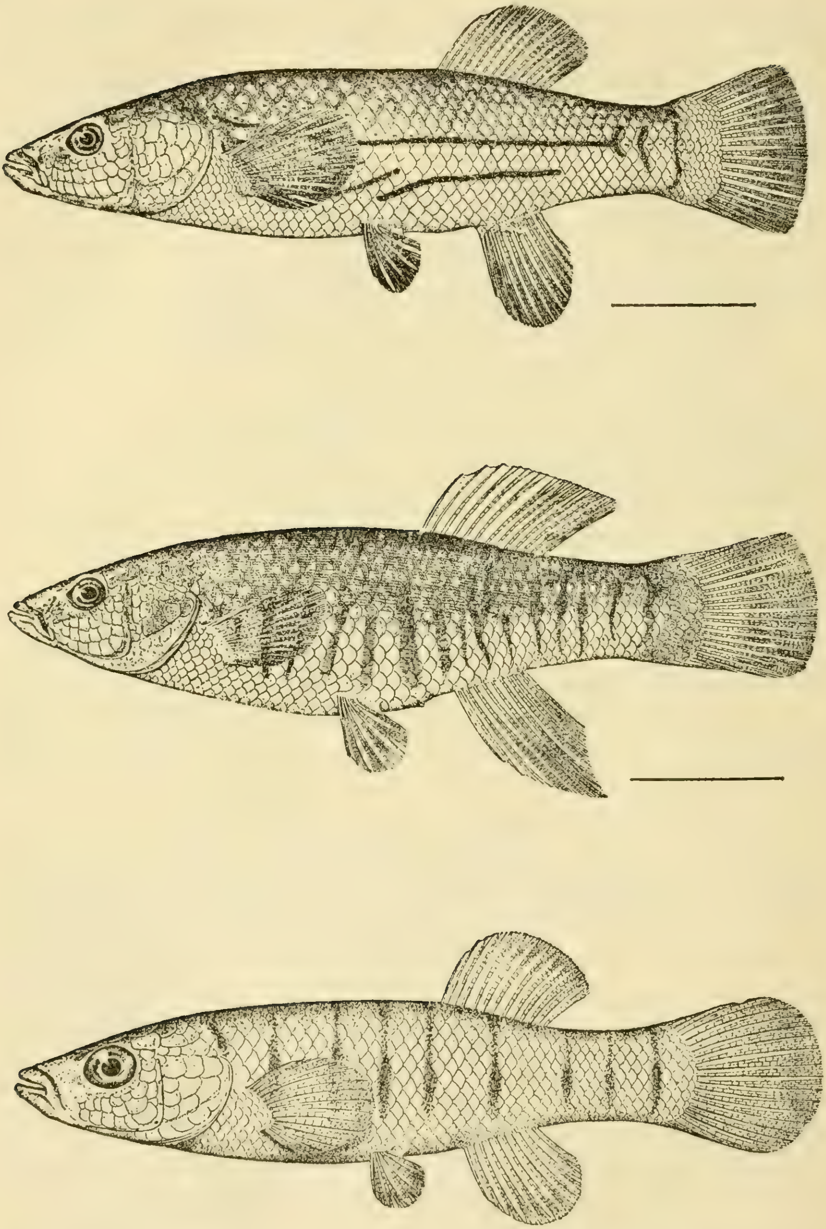

FIG. LXXVII. Striped killifish. *Fundulus majalis* Walbaum. Male above, female between and young below. (From Jordan and Evermann, U. S. Nat. Mus., *Bul.* 47).

THE FRESH WATER KILLY (*Fundulus diaphanus* Le Sueur) which reaches a length of about five inches, has the same range as the common killifish, but shows a tendency to confine its movements to open channels and currents. The young mingle and move with the common killifish, but as they grow older separate more. This species differs from its allies in that it has a tail squarely cut off and not rounded. The females are olivaceous. The sides are traversed by fifteen to twenty pearly white crossbands.

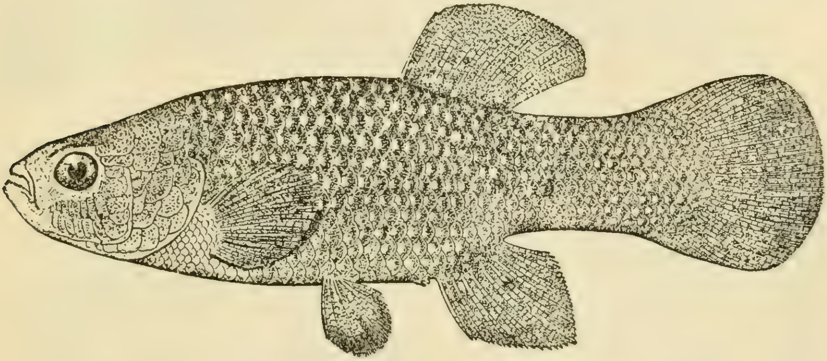

Fig. lxxviii. Common killifish. *Fundulus hetoroclitus macrolepidatus* Walbaum. Male. (From Jordan and Evermann, U. S. Nat. Mus., *Bul.* 47).

THE RAIN WATER FISH (*Lucania parvia* Baird) is a very small species, ranging from one and one-half to two inches in length. The males are olive or pale brown, with bluish reflections; the edges of the scales are darker. The females have pale olive fins without black spots or edging. In life the body is almost transparent. This species appears to be confined to the south Jersey marshes. It is not an active fish nor is it a top feeder. It does not overrun the marshes like the killies.

THE SHEEPSHEAD MINNOW, otherwise known as the "variegated minnow" and "pussy minnow" (*Cyprinodon variegatus* Lacépède) occurs everywhere along the Jersey coast. Like the preceding species it collects in pools. Both this and the rain water fish will live in ditches and pools foul with noxious gases. The general appearance of the sheepshead minnow is quite sufficient to separate it from the preceding species.

Speaking of all this species, Mr. Seal (23) says: "Breeding, principally, in shallow pools left on the mud flats by the receding tides, the young appear in the spring in enormous numbers and remain there until they attain a considerable growth—one and one-half or two inches—when they begin to run in and out with the tide. As the tide covers the marshes and flats, these fishes move with it in an unbroken line like a heavy line in battle, feeding as they go. The chance of a mosquito larva escaping them is infinitesimal. Any waters to which these fishes have free access will be searched in vain for mosquito larvae."

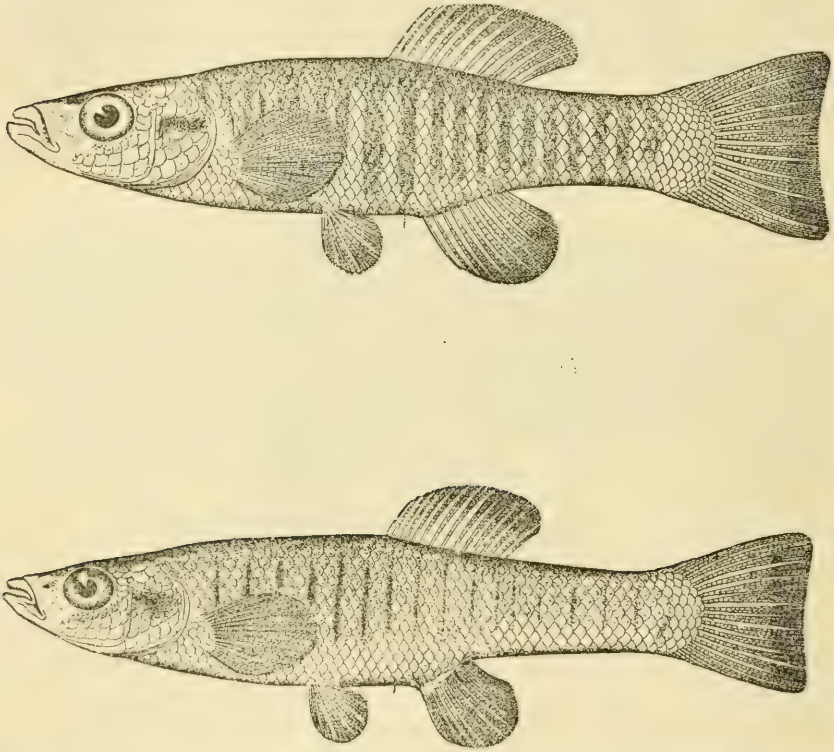

FIG. LXXIX. Fresh water killy. *Fundulus diaphanus* Le Sueur. Male above, female below. (From Jordan and Evermann, U. S. Nat. Mus., *Bul.* 47).

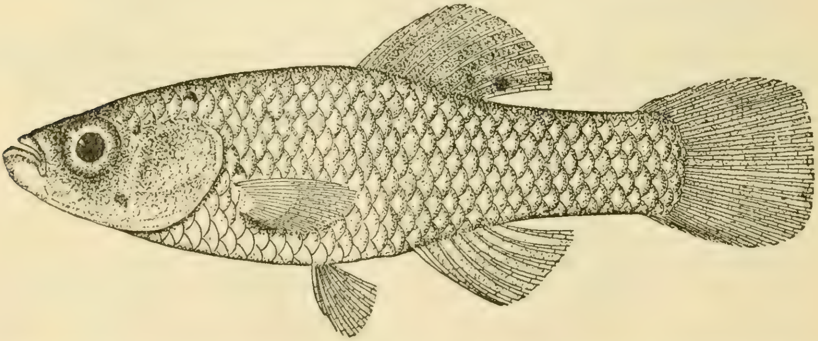

FIG. LXXX. Rain water fish. *Lucania parvia* Baird. (From Jordan and Evermann, U. S. Nat. Mus., *Bul.* 47).

In the years 1914 and 1915 Dr. F. E. Chidester (4) undertook and carried out an intensive study of the fish enemies of the salt marsh mosquitoes. The investigations showed clearly that the common killy (*Fundulus heteroclitus*) is by far the most important fish enemy of the salt marsh mosquito but that the fresh water killy (*Fundulus diaphanous* Le Sueur), the sheepshead minnow (*Cyprinodon variegatus* Lacépède), and the top minnow (*Gambusia affinis*—Baird and Girard) are commonly associated with it and play a strong secondary part.

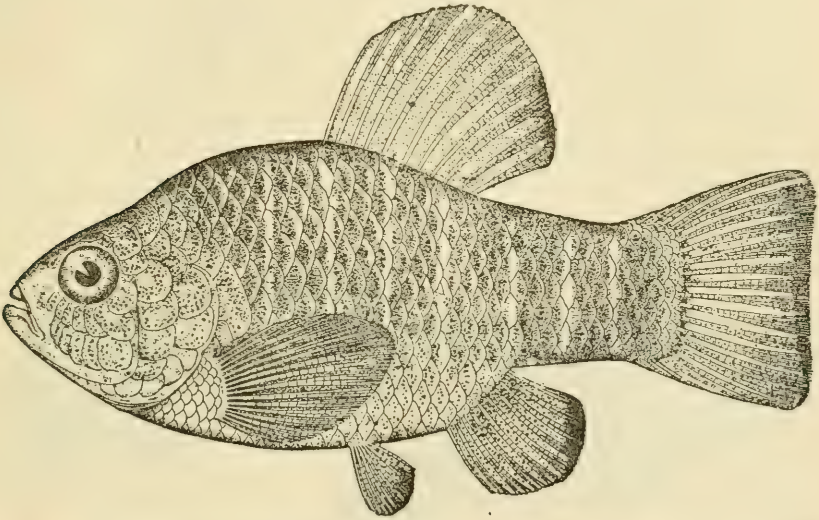

FIG. LXXXI. Sheepshead minnow. *Cyprinodon variegatus* Lacépède. (From Jordan and Evermann, U. S. Nat. Mus., *Bul.* 47).

Dr. Chidester's studies showed that this common killy migrated to the shallowest pools of the salt marshes and traveled up streams into water of very low salinity, that when in land-locked pools it is able to maintain itself over winter by burying itself in the mud, but that when the way is open it will return to deep water and come to visit the marshes when the temperature reaches 45°F. In land-locked pools these fish burrow into the mud to a depth of from six to eight inches, when the temperature of the water reaches 45°F.

Dr. Chidester's work shows that the inland migration of the common killy begins as early as the latter part of March and that egg-charged females are found as early as April 19. In the early spring three types of this species enter and spread in the marshes; larger males and females, the latter of which will lay eggs in a week or two; medium sized (one-half grown) which will not lay eggs for a month; and the small

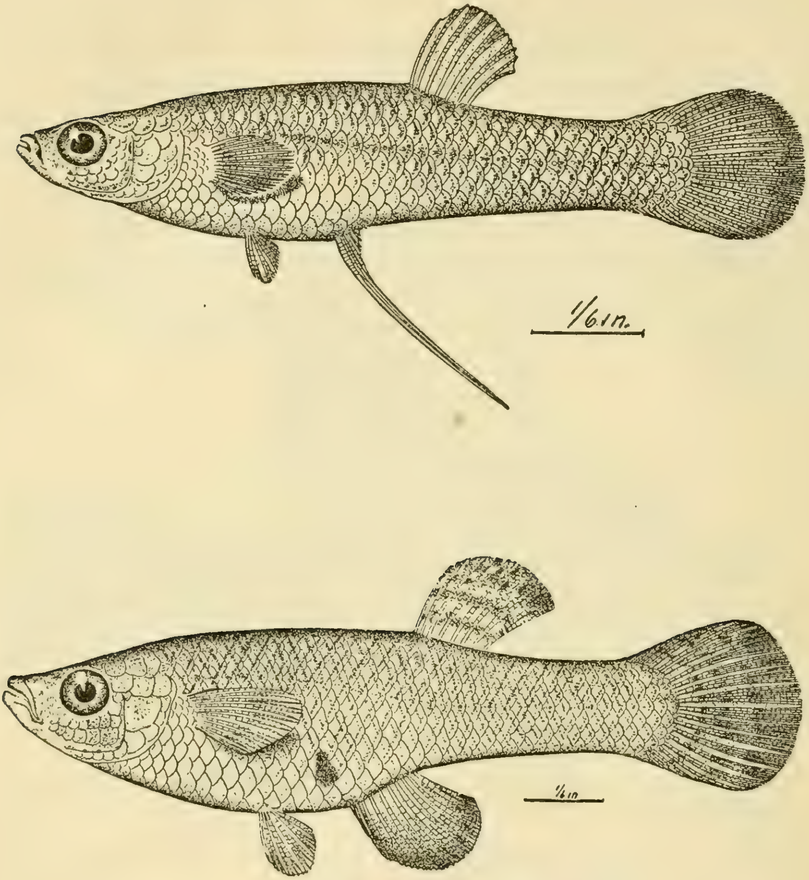

FIG. LXXXII. Top minnow. *Gambusia affinis* Baird and Girard.

fish which are the products of the previous year and which will not lay eggs until toward the end of the season.

The eggs of the common killy fall to the muddy bottom and then undergo development. In about three weeks the eggs complete development and the young fry hatch. From the time it is large enough the common killy feeds voraciously on mosquito wrigglers whenever it can get them. A single medium-sized fish will consume as many as fifty wrigglers a day.

In fresh water the minnows of game fish and various small fishes, such as the sunfish (*Lepomis sp.*) and top minnow (*Gambusia sp.*) are as effective against mosquito larvae as the killifish in salt and brackish water.

Whether in salt or fresh water marsh grasses and aquatic plants grow abundantly and frequently form a screen behind which mosquito larvae may develop. Sometimes a lily leaf will carry a film of water on its surface in which mosquito larvae can develop safely screened from hungry fish. Naturally the removal of such screens stops mosquito development by allowing the fish to find the wrigglers.

Dr. Smith was greatly impressed with possibilities of the top minnow (*Gambusia affinis*) as a destroyer of mosquito larvae. In his report for 1904 he has the following to say about this species:

"This is a very active species, being constantly in motion, a top feeder, and penetrates to the shallowest edges of the waters it inhabits. Being very small and slender, it easily glides over masses of aquatic plants and penetrates among them as no other fish does. It has been tested in small ponds and tubs during two summers and no mosquito larvae make their appearance when it is present, while *Anopheles* will appear in similar places where there are goldfish and other fish. Two top minnows will keep a tub clear of mosquito larvae. They breed rapidly, bringing forth young several times in a season. When extruded, they are many times larger than the newly hatched goldfish and, having no umbilical sac, they begin to prey at once.

"Among the fishes of New Jersey there is none that quite fills the place of this *Gambusia* for choked-up streams and swampy areas. It lives in fresh water as readily as it does in brackish, and does well in captivity or restricted areas generally. Its ability to get along in the merest film of water over a lily leaf, where *Anopheles* larvae find safety from other fish, gives it a field of usefulness whose importance cannot be overestimated.

"Mr. Seal writes on this point: 'The seacoast of New Jersey is, in my opinion, amply protected so far as fishes are concerned. I do not think you can improve on *Fundulus*, *Cyprinodon*, and *Lucania* for the marshes of the coast. And as for the shore waters of the Delaware and its open tributaries, *Fundulus* will do the work. But there are thousands of 'branches' which connect with the creeks by sluices, and which are sluggish and dense with plants. This, therefore, is a separate problem from that of the coastal waters proper.

"It is my belief that it would be wise to place *Gambusia* in the head water 'branches' of the cedar swamp-fed streams, such as the Rancocas, Big and Little Egg Harbors, and others, and from these small spring-fed tributaries, many of which never freeze over, let them spread down the streams. I am satisfied that if we go about it right, there will be no trouble in introducing them to such waters; and in thinking the matter over in connection with such places as I know of as being suitable, I conclude that spring would be much the best time for the experiment, for the reason that pike and other predaceous fishes collect about the deep holes and spring places in winter, and *Gambusia* would have little chance for escape, whereas in the spring they could find protection among the plants and in the shallows where the others could not reach them. Another consideration is that in fall we should be submitting a few thousands to new and unfavorable conditions at the most unlikely time of the year, whereas if we put the same number out in the spring, by fall we can reasonably expect that there will be tens of thousands, thoroughly familiar with and adapted to the waters in which they began life, and, having known no other, there will be no question except that of temperature involved.

"I have seen *Gambusia* collected in vast numbers where there was thin ice, at Cape Charles, Virginia, and I have no doubt they passed the winter in those places, where probably the ice was at times two or three inches thick, or even more.

"This would be an ideal species to introduce into ornamental ponds in which aquatic vegetation forms an important feature. Such ponds having no fish save those which are placed in it would allow this little species to develop unchecked and would absolutely prevent all danger of mosquito breeding."

Since Dr. Smith's report, the top minnow has been located in certain sections of southeastern New Jersey, and various attempts have been made to plant it, but in no case has it been able to persist much out of its natural range. It goes along during the summer, but disappears during the winter. Although the experience has been discouraging it has not been really conclusive. Furthermore, carefully directed experiments should be made.

But throughout the recorded history of the mosquito, after the utmost has been done by natural enemies, the pest still appears at times and places in terrible proportion.

The activity of animal and plant enemies of mosquitoes seems to be at its maximum in permanent bodies of water with a reasonably fixed level because such water condition affords many of these animals a sufficient continuous food supply to preserve their lives and activity.

In midsummer a brood of mosquitoes can hatch from the eggs, complete larval development, complete pupation, and emerge as adults in a period of from seven to ten days. This life cycle is extremely short, materially shorter than the life cycles of the better known natural enemies. Since mosquito larvae and pupae appear suddenly in immense numbers, stay only a short time, and fly away as adults, the mosquito cannot serve as a continuous article of diet.

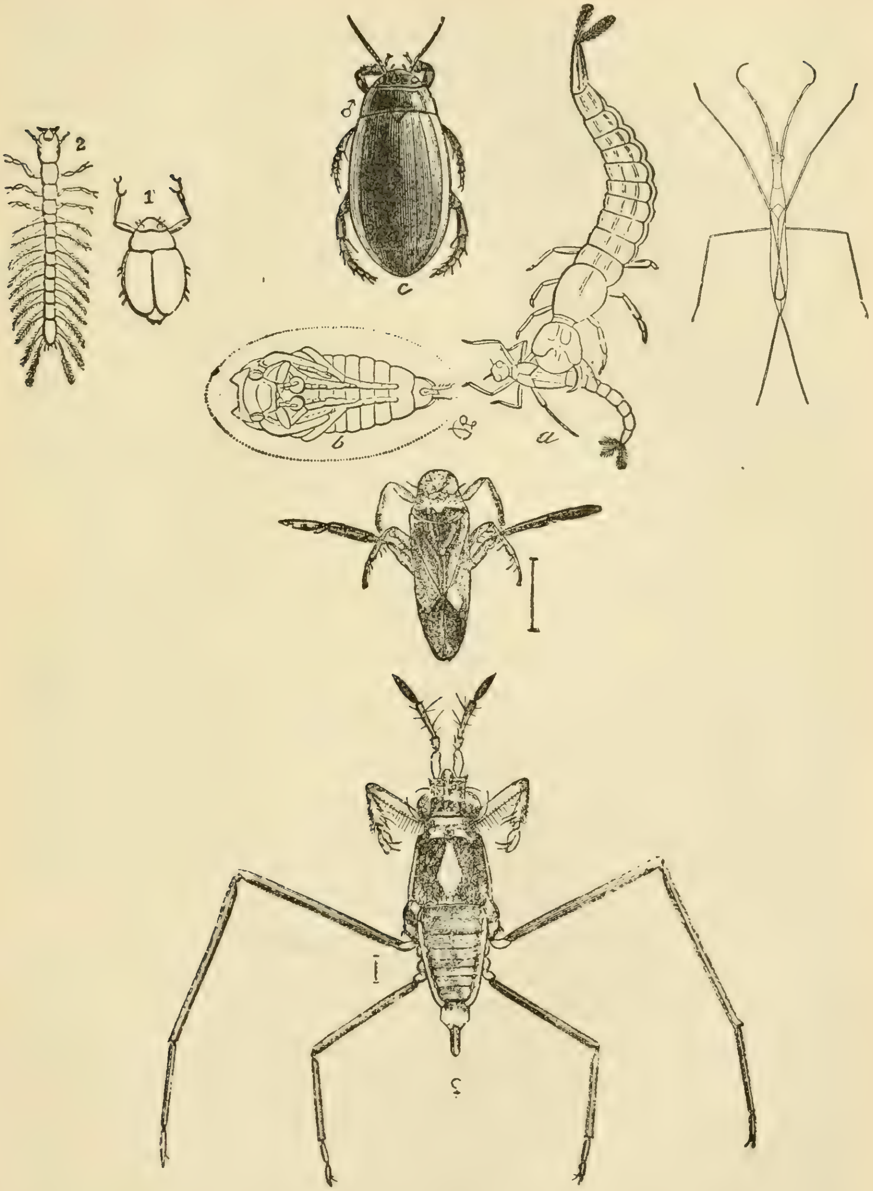

FIG. LXXXIII. TOP LEFT: A whirligig beetle (1), and its larva (2), natural size. TOP CENTER: A diving beetle, *Dytiscus marginalis*. A, larva, or water tiger devouring an agrion larva; b, pupa; c, male beetle. TOP RIGHT: A Water-scorpion, *Ranatra fusca*. CENTER: A water-boatman, Notonecta species. BOTTOM: A Water-strider, *Rheumatobates rileyi*, female.

As we have seen, the only enemy of the mosquito which is maintained in sufficient numbers to penetrate large areas of recently overflowed land and eat up an enormous number of mosquitoes before they can emerge are the salt marsh minnows. In dealing with the same problems in recently overflowed lands along the course of a river, although the stream may be well charged with minnows, the area overflowed is usually so large that the supply of minnows is totally inadequate to do the job. The salt marsh minnows are apparently anxious to penetrate the salt marsh everywhere while the tendency of the fresh water minnow is to stay in the more open water.

An idle dream in the New Jersey experience is the idea that a sump hole in the midst of a temporary marsh in which predatory insects are maintained will support a sufficient supply of them to eat up the billions of mosquito larvae that hatch. Thus, except on the salt marshes, the work of natural enemies has to be supplemented by the use of larvicides and other methods of control.

ATTRACTION OF MOSQUITOES TO MAN

It is a well known fact that mosquitoes are attracted to the human and animal kind for purposes of sucking blood. The writer has frequently observed at dusk, while sitting in a screened enclosure with little or no wind blowing, that female mosquitoes (*C. pipiens*, *A. vexans*, and *M. perturbans*) concentrate on the screen wire directly over the spot where he or others were sitting and that no such concentrations appear elsewhere on the screens. Thus it seems evident that the attractive materials are gaseous and emanate from the body.

Rudolfs (19) undertook to find out what materials having the human body as origin attracted mosquitoes. Under the heading of urine and perspiration decomposition products he studied urine, urea, glycocoll, cystine, phenylalanine, aspartic acid, asparagine, glutaminic acid, alanine, trypsin, tyrosin, gliodin, ammonium hydroxide (strong), ammonium hydroxide (1 to 200), ammonium hydroxide (one-half drop of weak solution on a strip of paper), acetic acid two per cent (drop on piece of paper), and sweat. Under the head of sebaceous secretions and substances found in it, he studied sebaceous secretions (human), handkerchief rubbed on cow's back while hundreds of mosquitoes were alighting and biting, cholesterol, oleic acid (drop on paper), benzoic acid, oleic acid and benzoic acid, oleic acid and cholesterol, and stearic acid. Under blood and some constituents, he studied human blood (fresh), cow blood (fresh), beef (fresh), beef (boiled), beef bouillon, blood albumin and hemoglobin. Under possible attractive agents, he studied pepsin, dextrose (fermented), peptone, ammonium carbonate, ammonium carbonate (1 to 1,000), glycerin, sugar solution, valeric acid (strong), valeric acid (weak, one per cent), lactic acid, indol (0.1 per cent sol.), skatol (0.1 per cent sol.), vaseline (blue seal), rancid olive oil, and shark liver oil. Under the head of other agents produced by the human body, he studied breath, temperature, moisture, carbon dioxide, carbon dioxide and moisture, carbon dioxide and temperature, carbon dioxide and ammonia.

The upshot of these studies may be stated as follows: ". . . combinations of carbon dioxide, ammonia, moisture and temperature, such as appear in the human breath are the most attractive materials found." Rudolfs concludes that carbon dioxide and ammonia play the important rôle in attracting mosquitoes.

Since the completion of Rudolfs' work the writer has used ammonium carbonate and carbon dioxide in connection with regular mosquito traps and found that while either increases the trap catches, carbon dioxide produces far greater increases than ammonium carbonate. It seems that the evolution of ammonia from the ammonium carbonate reaches concentrations that are repellent.

In September, 1933, an attempt was made to measure the effect of carbon dioxide as an attractant. Two regular vertical mosquito traps were set up in Dayton, New Jersey, about 150 feet apart. By preliminary operation minor but not consistently different catches were taken in those two traps. A tank of CO_2 was secured and copper pipe run from it to the selected trap. This pipe passed through a coil located just above the frosted bulb, thence through a water bottle, and thence to the peak of the cap of this selected trap. The passage of the gas through the coil above the lamp bulb was designed to heat it and the passage of it through the water was designed to moisten it. As gas bubbled through the water and was delivered just above the peak of the trap it filtered down over the peak and some, but not all of it, was caught by the air stream blowing into the trap and carried with this air stream out through the trap in the direction of the ground.

Operation of both traps began each day at 7:00 P.M. and continued until 7:00 A.M. Delivery of the carbon dioxide through the selected trap began each day at 7:00 P.M. and ceased at 9:00 P.M. One trap ran with a twenty-five-watt frosted bulb as the sole attractive agency while the other trap ran with a twenty-five-watt frosted bulb as did the first but in addition for the period from 7:00 P.M. to 9:00 P.M. each evening had carbon dioxide gas distributed over its hood. (See Table IX.)

MOSQUITO FLIGHT

Howard, Dyar, and Knab (14) have brought together a group of data bearing on the question of mosquito migration (Table X).

It thus appears that the far-migrating species are those which breed on the salt marshes, that twenty-five or thirty-mile movements are common, and that extremes of sixty miles may be reached.

TABLE IX

Date	Trap without CO_2 but with Light		Trap with CO_2 and Light	
Sept. 1933	All Species	pipiens	All Species	pipiens
1	16	12	113	85
3	24	10	185	68
4	54	12	205	74
5	95	28	363	59
6	38	12	154	43
7	22	9	402	134
8	134	28	317	81
9	58	16	411	111
10	81	31	405	89
15	20	7	21	12
19	23	12	39	18
Totals	565	177	2,613	774
pipiens		31.4 per cent		29.7 per cent

The addition of carbon dioxide for two hours each evening on an average increased the catch of female mosquitoes from 565 to 2,613 or 4.62 times.

TABLE X

Data on Mosquito Migration

Date	*Investigator*	*Place*	*Species*	*No. of Miles*
1879	Mitchell	Matagorda Bay	Unknown; probably salt marsh	50–60
1884	Hetherington	Ship "Gedney"	Unknown	27
1886	Mitchell	Matagorda Bay	Unknown; probably salt marsh	50–60
1903	Russell	Ship "Newark"	*An. annulipalpis*	2
1904	Smith	N. J. Sea and bay coast	*A. sollicitans* and *A. cantator*	30–40
1904	Carter	Gulf of Mexico La. coast	*A. niger*	15–18
1908	Mayer	Dry Tortugas	Salt marsh	40
1909	Young	Ship "Concho"	Unknown	60

The author (10) records tracing both *A. cantator* and *A. sollicitans* far into the territory lying back of the salt marsh from which they come. He says that in New Jersey twenty-five-mile migrations of these species are common and that thirty-five to forty-mile migrations occur when broods are large and weather conditions favorable. He makes the point that *A. cantator* does not go as far as *A. sollicitans* and states that the difference may be due to the cooler weather prevailing when *A. cantator* takes wing.

Dr. D. P. Curry, Assistant Chief Health Officer of the Panama Canal Zone, records the arrival of a brood of *A. sollicitans* aboard the SS Cristobal on September 11, 1937, while the ship was enroute to New York from Cristobal and Colon. When this brood appeared the ship was located off Cape Henry, 110 miles from shore. The brood was a large swarm of mosquitoes sufficient to render the passengers uncomfortable. The mosquitoes arrived suddenly. *A. sollicitans* is not produced in swarms in Colon and Cristobal or anywhere in West Indies and only to a limited extent on the southern coast of the United States. It is therefore evident that this brood winged its way over the ocean from the American shore to the ship 110 miles away.

Russell (see Table X) has shown a flight of two miles for *An. annulipalpis*. LePrince and Orenstein (17) have cited incontrovertible evidence to show a flight of 6,250 feet by *An. tarsimaculata* and *An. albimanus* (the latter a very important carrier of malaria).

The author (10) has collected evidence to show movement of *C. pipiens* from an area of very intense breeding to a point fully 2.5 miles away.

Smith (23) records the fact that *A. vexans* may migrate as far as five miles. The author (10) has published evidence that this species sometimes moves as much as ten miles and that this movement is influenced by topography. Clarke (5) has shown movement of this species of a little more than fifteen miles and in plains country that this movement is radial in character. Matheson (18) records movements of *M. perturbans* of at least fifteen miles.

Thus the recorded facts seem to show that certain salt marsh forms readily move thirty-five to forty miles and show an extreme distance of 110 miles, that malarial mosquitoes move from one to two miles, that the fresh water swamp mosquitoes move ten to fifteen miles, that the principal house mosquito moves at least 2.5 miles, and that distance of movement is probably correlated with density of emerging brood.

The woodland pool mosquito group has thus far shown no long flights, but may show something of the sort with further study.

The cause of mosquito migrations is obscure, but it is safe to assume that they are in some way related to one or both of the great necessities of living matter—persistence of the individual and reproduction of its kind.

When the mosquito emerges from its pupal skin, its body wall hardens, its parts become adjusted, and it flies away in search of food and opportunities for reproduction. Usually these desired conditions are found nearby. The female alternates between places where food may be had and places where eggs may be laid.

It seems likely that such simple type of spread is apt to be radial but there is no data to prove the point.

In a species that lives in the wilds, such as the more important species of *Anopheles* the movement to secure food may take on a different character. LePrince and Orenstein (17) have shown that *An. albimanus* and others make their way for a distance of over a mile to a village, apparently in search of food, and that they or others of the same species make a return flight before morning. This does not sound like a case of radial distribution, but more like a directive movement to a definite point for a definite purpose.

When dealing with the fresh water swamp mosquitoes, such as *A. vexans*, breeding intensively over a large area, the outward movement as shown by J. Lyell Clarke, chief executive of Desplaines Valley Mosquito Abatement District, is definitely radial. Clarke's work was done in a plains country. The author has shown that in broods produced in a hilly country the outward movement is irregular, passage over the mountains taking place through the gaps and migration proceeding farther in the direction of great populations.

As has been shown, carbon dioxide is a powerful attractive agent. Green plants void carbon dioxide at night and the human kind at all times. Since the population as well as the factories of great cities are producing vast amounts of carbon dioxide, it seems logical that mosquitoes might be drawn to these cities and the usual migration pattern characteristic of the open country be considerably modified.

A warm temperature, 80°F., is extremely favorable. Light is avoided by most species and some have such abhorrence of it that they will not become active while it is strong. Atmospheric moisture has a very powerful effect upon the adult. High percentages are favorable and low percentages deadly. Rain itself is decidedly injurious and prevents mosquito activity.

Air movement also greatly influences mosquito activity. A stiff breeze is usually quite sufficient to stop their movements and to compel them to cling to shelter. Winds of low velocity (ten miles or less per hour), of high temperature (80°F.) and high humidity appear to be the ones that favor long flights.

The observations of practically all investigators indicate that the salt marsh species in long migrations travel with the wind. On the other hand, LePrince and Orenstein (17) found *Anopheles* flying against the wind or at right angles to it. Russell, however, records *An. annulipalpis* as coming aboard ship on a breeze from land. The investigations of the author and later of Clarke show that the movements of *A. vexans* do not follow prevailing winds.

The available facts on adult mosquito movements indicate the necessity of knowing the composition of the mosquito fauna throughout the territory to be given protection so well and so thoroughly that adequate measures may be taken to eliminate invasions from outside the boundaries.

6

THE HISTORY OF MOSQUITO CONTROL IN NEW JERSEY

A NUMBER OF PERSONS, among whom should be included particularly Dr. John B. Smith and Spencer Miller, were giving serious thought to the mosquito problem in New Jersey previous to the turn of the century. In 1900 Dr. Smith secured from the director of the New Jersey Agricultural Experiment Station a small sum of money for a preliminary investigation.

On June 27, 1901, Dr. Smith sent out the following communication over his name to the various boards of health in the state:

"It is my intention to devote some time during the present season to an investigation of the mosquito question as it exists at the present time in New Jersey. The recently established connection between malaria and mosquitoes makes this matter important from the sanitary standpoint and gives it a direct bearing upon the health of the community. For this reason I have asked the cooperation of the State Board of Health and have received from its secretary, Dr. Henry Mitchell, cordial assurance of support.

"It is necessary, however, to make my work complete, that I should also enlist the cooperation of local boards throughout the state; therefore I beg you for information on the following points:

"1. Is 'malaria' a prevalent disease within your jurisdiction, *i.e.* are the cases at all numerous?

"2. If cases are numerous, are they localized, or are they scattered throughout the community?

"3. Is one case apt to be followed by others close by?

"4. Are mosquitoes numerous in your jurisdiction, and if so, are they generally spread or is one part of the district more infested than others?

"5. Have you observed any relation between the abundance of mosquitoes and the prevalence of malaria?

"6. If mosquitoes are plentiful can you tell where they breed?

"7. Will you send me from time to time specimens of the troublesome mosquitoes in your jurisdiction? I will supply as many vials as are needed, and will be glad to give whatever information is desired as to methods of collecting and preserving.

"8. Any further information bearing on the above matters is desired and will be appreciated.

"It may be added that the information obtained will not be published in such a way as to prejudice any particular locality; but is necessary to establish facts and relations. It is also to be used as a basis for recommending measures to mitigate or locally abolish the mosquito pest."

In the same year the South Orange Improvement Association, under the leadership of Spencer Miller, initiated a local campaign against the pests and secured Dr. L. O. Howard, chief of the Bureau of Entomology, to lecture in South Orange on that subject on May 16, 1901. Following this lecture the South Orange Improvement Association carried on a campaign throughout that season and each season following until the work was taken up on a broader basis.

In the meantime interest in mosquito control had made its appearance among the residents of the north shore of Long Island. This interest seems largely to have been stimulated by the work of Henry Clay Weeks and to have involved William J. Matheson, Paul D. Gravath, C. B. Davenport, and others.

For the sake of clearness it seems to be advisable to give a separate account of the activities of each of several groups, all of which were working in one way or another along lines of mosquito suppression.

Sufficient progress was made by Dr. Smith with the appropriation of 1900 to enable him to induce the Legislature of the state in the year 1902 to pass an act authorizing the sum of $10,000 for a study of the mosquito problem. This act and subsequent ones mentioned here are quoted in Chapter 9 of this book.

Unfortunately the appropriation committee failed to provide the money, and the work was continued during the following summer only through the interest of Governor Murphy, who set aside from his emergency fund the sum of $1,000 for this purpose. The appropriation committee of the 1903 Legislature provided the funds contemplated in 1902.

With the necessary funds in hand Dr. Smith planned and carried out a very careful study of the structural characters, the life history and habits, and methods of controlling the principal species. He proved for the first time what was stated in Chapter 1, that salt-marsh-bred species migrated for long distances over the upland, reaching points more than thirty miles away in large numbers and infesting seriously more than one-half the state's land surface and annoying very seriously nearly three-fourths of her population.

With facts derived by this study in hand, the State Legislature was induced to pass an act in 1905 providing for state aid to communities that cared to spend their own funds in salt-marsh drainage for mosquito control.

Local authorities with one exception, Elizabeth, utterly failed to take advantage of this law and all the money appropriated, with the exception of $1,000 which was spent on the Elizabeth marsh, was returned to the state treasury.

During 1905 Dr. Smith caused a rapid survey of the entire salt marsh to be made and calculated on the basis of that work that the necessary initial drainage could be completed by the expenditure of $350,000. With the facts in hand the State Legislature enacted a law charging the New Jersey Agricultural Experiment Station with the duty of draining the salt marsh with such portions of the $350,000 as the appropriations committee could be induced to give from year to year.

Beginning in 1906 the drainage of the salt marsh for mosquito control went forward on the basis of the act last quoted until its efforts were supplemented in the year 1912 by an act which is known as Chapter 104, Laws of 1912.

The local campaign against mosquitoes in South Orange, under the leadership of the South Orange Improvement Association, beginning in 1901, continued steadily each year until it was taken over by the Essex County Mosquito Extermination Commission and carried on under the provisions of Chapter 104, Laws of 1912.

In April, 1902, another anti-mosquito movement was started in Elizabeth. There sixteen citizens subscribed twenty-five dollars each for field work toward overcoming the pest. This was spent in oiling and draining a small portion of meadow at the foot of Schiller Street.

In April, 1903, the Elizabeth Board of Health, with a $1,000 appropriation, dug 40,000 feet of ditches, draining some 190 acres. These were the first ditches to be dug by machine.

The next to fall in line was Newark. Active work, though, was not started until 1904, the Common Council that year voting the sum of $5,000 for that purpose, having refused an appropriation the previous year.

On May 5, 1903, the Newark City Board of Health appointed one of its members, Frederick W. Becker, M.D., a committee to inquire into the question of mosquito extermination. Several reports were submitted.

On July 7, 1903, Dr. Smith read a paper on mosquito elimination, and also exhibited a map of the Newark meadows, made for the occasion, on which he showed where most breeding occurred. A week later, the following notice was sent out:

Newark, N. J., July 14, 1903.

Dear Sir: Your presence is requested at a meeting to be held in the rooms of the Newark Board of Health, 880 Broad Street, on Friday evening, July 17, 1903 at 8:30 o'clock, for the purpose of discussing the problem of mosquito extermination.

There will be present gentlemen from the boards of health representing the various communities within our mutual sphere of interest. As only through hearty cooperation may we expect relief from this pest, it is earnestly hoped that you will be present.

Respectfully,
F. W. Becker, M.D.

This was the first attempt made in New Jersey for the extermination of the mosquito through cooperative endeavor.

Pursuant to this notice a meeting was held with representatives from Orange, Harrison, Summit, Springfield, Bloomfield, South Orange, Irvington, Montclair, East Orange, Belleville, Vailsburg, Millburn, Elizabeth, and Newark. It was decided that a temporary organization be formed with a view of making it permanent. Dr. Becker was elected temporary chairman. The following were appointed the Committee on Organization: Dr. F. W. Becker, Newark; S. P. Gilbert, Bloomfield; and H. F. Parker, Montclair.

A Legislative Committee was appointed at this meeting consisting of the president, Dr. T. N. Gray, chairman; Spencer Miller; J. B. Thompson; S. P. Gilbert, and Louis J. Richards, secretary.

That winter this committee drew up a bill which was introduced in the Assembly in February, 1904, by Honorable Edward D. Duffield, Assemblyman from Essex County. It was passed and signed by Governor Stokes on March 28, 1904. This is known as the Duffield Act, Chapter 119, Laws of 1904. It is an important mile-stone in the progress of our work, and no occasion has since arisen to change it materially.

At a meeting of the Conference Committee on Mosquito Extermination, held on May 19, 1904, the Legislative Committee reported that the anti-mosquito clause had been passed by the Legislature, and was now a law and a part of the General Health Act.

The following gentlemen composed the original Conference Committee on Mosquito Extermination:

New Brunswick, Dr. John B. Smith
Orange, Herbert Richards; William Schleuer
Harrison, John Malone; John J. Scanlon
Summit, T. J. Scott
Springfield, J. L. Denman; Dr. Stiles
Bloomfield, Seymour P. Gilbert
Newark, Dr. F. W. Becker; D. D. Chandler
Arlington, John B. Thompson
South Orange, Spencer Miller, C.E.
Irvington, J. K. Clickenger; Hugh Winkler
Montclair, Horatio F. Parker
East Orange, E. M. Brewster; Dr. T. N. Gray
Belleville, Dr. John F. Condon
Vailsburg, Dr. P. R. Davenport
West Orange, Mr. Grady
Glen Ridge, John A. Brown; John B. Smith
Plainfield, L. R. Thurlow
Kearny, John B. Thompson
Elizabeth, Louis J. Richards

On October 8, 1905, Dr. T. N. Gray took the presidency, succeeding Dr. Becker.

In 1910, the name of the association was changed to the North Jersey Mosquito Extermination League. Dr. N. Elliot was secretary, but his minutes have been lost. He resigned on May 20, 1912, Louis J. Richards taking his place.

The North-Shore Improvement Association of Long Island, with offices at 49 Wall Street, New York City, published on October 1, 1902, an account of anti-mosquito work done in the association's territory by Frank E. Lutz and William W. Chambers, in which it was shown that a vast amount of interest had been stimulated and that the mosquito problem in that section of Long Island had received a pretty thorough investigation. The work of this association appears to have lagged as the years went by until 1914, when a bill was enacted by the Legislature of the State of New York creating the Nassau County Mosquito Extermination Commission.

In 1903, there was formed in New York a National Society for the suppression of the mosquito pest, known as the American Mosquito

Extermination Society, under the leadership of William J. Matheson as president, and Henry Clay Weeks as secretary. A convention was held in December of that year and later a little folder entitled "Mosquito Brief of the American Mosquito Extermination Society" was published. A summary of most of the main facts concerning the mosquito problems as we know them today is set forth in this little folder and the publicity which the movement received did much toward making the layman understand the nature of the problem. After a comparatively short career this society ceased to be an active factor in mosquito work.

About the year 1904 Dr. Alvah H. Doty, then health officer of the Port of New York, became vitally interested in the problems of mosquito control within the limits of the city and led a movement which resulted in the establishment of a large amount of salt-marsh drainage in Staten Island and about the City of New York itself. After Dr. Doty ceased to be connected with this phase of the city work the work of mosquito control lagged for a number of years. In the year 1915, under the leadership of Dr. Haven Emerson, then health officer of the City of New York, an appropriation of $150,000 was made for the purpose of finishing the drainage of the salt marshes within the limits of Greater New York. This work was carried on under the immediate direction of Eugene Winship, sanitary engineer of the Department.

It will be remembered that since 1906 the New Jersey Agricultural Experiment Station has been steadily engaged in installing as large an amount of salt-marsh drainage as the funds, which the Legislature, saw fit to appropriate annually, would permit. It will also be remembered that the various local campaigns have been steadily continued and extended. All this work in the year 1912 crystallized in the form of a bill which passed the Legislature and became a law under the title of Chapter 104, Laws of 1912. This act is known as the County Mosquito Extermination Commission Law and provides for the appointment of a non-paid mosquito commission in every county in the state. The duty of this commission is to formulate plans, secure funds, build, and operate an organization for the suppression of the mosquito pest.

Under the provisions of this law the appointing power was lodged in the hands of the Supreme Court judges and the New Jersey Agricultural Experiment Station was designated as the centralizing and general directing agency.

Under the terms of this act, Chapter 104, Laws of 1912, Sussex, Morris, Passaic, Bergen, Hudson, Essex, Union, Middlesex, Monmouth, Ocean, Atlantic, and Cape May Counties have undertaken the active work of mosquito control.

The New Jersey Mosquito Extermination Association, state-wide society, organized for the special purpose of furthering anti-mosquito work in the state in all its phases, was formed in the year of 1913 by representatives of the mosquito commissions created under the authority of Chapter 104, Laws of 1912, the State Agricultural Experiment Station, and certain interested private citizens. This association has now held thirty-one annual conventions and published proceedings of each convention.

The Associated Executives of Mosquito Control consists of the employees, superintendents, and assistants of the mosquito commissions, holds regular monthly meetings and has become a strong and powerful factor in forwarding mosquito control work.

No effort is made in this historical presentation to give attention to extensive mosquito work which has arisen elsewhere in the country. Perhaps the earliest movement of this sort occurred in the State of Connecticut where a well-established program is in operation. More limited work has been undertaken in Rhode Island and Massachusetts. More recently the State of Delaware has undertaken mosquito control on a large scale. The United States Government has become vitally interested in mosquito control as a means of reducing the human disease of malaria, the work being done under the general supervision and control of the United States Public Health Service. The World Wars, through the establishment of military camps and shipyards, brought about a very large increased interest in control of mosquitoes. The availability of large amounts of labor during the last great depression has likewise made possible a great deal of mosquito work which could otherwise not have been done for many years.

Probably one of the most interesting developments in mosquito control has been the mosquito abatement district occurring in a number of mid-western states and in California. This idea apparently has arisen because political boundaries do not follow the topography of the country. The abatement district may include parts of different political entities. Such an abatement district is drawn up and presented to the voters living therein. The voters decide whether they will have it or not. If they decide to have it, public monies are automatically provided under certain conditions. The abatement district agrees in general with the first principle enunciated in the following chapter, that of elimination or treatment of breeding water, but fails to provide any centralized supervision and control. This failure is obviously due to the feeling that the abatement district may be made sufficiently large and complete not to be seriously influenced by mosquitoes coming from outside.

7

THE PRINCIPLES AND DETAILED PROCEDURE OF MOSQUITO CONTROL

THE MOST SUCCESSFUL HUMAN ATTACKS on the mosquito for the last twenty or thirty years have been centered on the larva as the most vulnerable stage. So far no practical means has been found of attacking the adult, the egg or the pupa, but research in these matters should be constantly prosecuted.

Basic principles of attacking the larvae follow:

1. Since the larval stage can live in water and in water only, elimination of mosquito-breeding waters or so treating them that they cannot support mosquito wriggler life means elimination of the mosquito pest.

2. Since adult mosquitoes fly some distance, the area over which mosquito work is done must be large enough to prevent migration of adult mosquitoes from invalidating mosquito work in that area.

3. Since adult mosquitoes fly over a range of from a few hundred feet to forty miles or more, the species of mosquitoes composing the fauna of the region where mosquito protection is desired must be known in order that the necessary size of the area to prevent serious flights may be determined.

4. Since the benefits of mosquito control work are generally distributed among all the people of the protected area, it should be financed from public funds and the burden of the elimination of mosquito-breeding places not placed on the individual property holder on whose place the particular breeding spots have been situated by nature.

The property owner whose holdings have been damaged should be adequately compensated.

5. Since the prosecution of mosquito control work is properly a public function and supported by public funds, the public organization must have the right of entry and the performance of necessary work on private property.

6. Since it is logical that mosquito works should be financed from public funds, the individual has no right to tolerate any condition on his property that will create additional mosquito-breeding places or

increase such as already exist naturally without himself providing adequate funds which can be used by the proper public mosquito control agency to eliminate the mosquito-breeding thus created.

7. Since the work of mosquito control deals with a living organism and must have the support and cooperation of the public, efficient prosecution of mosquito work requires a director of operations who is thoroughly grounded in the problem of dealing with living organisms (mosquitoes particularly), understands the principles of dealing with the human kind, and has a practical knowledge of engineering.

8. Since no two men employ the same methods and since the director of mosquito control operations is held responsible for economy and efficiency in mosquito reduction and elimination, the director should have utmost freedom in methods and in the formation and operation of the organization under him.

9. Since the responsible organization cannot safely depend solely upon the public reaction as a measure of efficiency of mosquito control going on under its directions, it must provide some reasonably reliable means of determining the efficiency of its work in terms of mosquitoes on the wing.

Once each month during the warm season, as has been stated, the tides run high. The first brood of mosquitoes usually starts during late March or early April and reaches maturity in the last part of April or early May. Another comes out in June, another in July, another in August, and another in September. In south Jersey there may be another brood in October and still another small one in November.

While this regular succession of broods is the usual thing there are many exceptions. Sometimes, as a result of a long continued favoring wind, the tide will remain so high for ten days or two weeks, that the escape of water from ditched but shut-in marsh is impossible and a brood of mosquitoes will mature and escape. Sometimes the weather will be so rainy and cloudy that the complete removal of the surface water is impossible and a brood may mature and escape. On the other hand, sometimes the tides will pass the full-moon period without rising high enough to cover the marshes and no brood will develop. Sometimes the weather will be so hot and dry that the surface water on the marshes will evaporate before the brood of mosquitoes can mature and none will escape. Sometimes the tides will run so low that areas which are usually swept by high tides with sufficient frequency to prevent breeding may breed heavily.

Thus it appears that there are conditions during the mosquito season when almost no marsh will breed and still other conditions when almost any marsh will produce mosquitoes. In every case, however, study will show that to produce mosquitoes, warm water free from killifish must lie on the marsh surface long enough for maturity to be reached or mosquitoes will not be produced.

Briefly stated, the control of the salt marsh mosquito is a matter of so ditching the marsh that none of the waer which remains upon it will stagnate, but all will rise and fall with the tide and be everywhere penetrated by large numbers of killifish. The only exception to this rule is the permanent salt marsh pool which, being constantly stocked with killifish, turns off no mosquitoes. While it is true that low-lying sections of the marsh widely open to the tide, which are covered by practically every high tide, do not breed mosquitoes, it is also true that such areas under a series of low tides will sometimes turn off considerable broods.

High-lying or shut-in meadows over which the tide rarely sweeps are the breeders of salt marsh mosquitoes. Even where an extra high tide has stocked the holes with killifish the water dries up on the marsh surface generally and in the temporary pools, destroying the killifish. Water from rain and tides just high enough to trickle over the marsh through the grasses then fill the holes and the larvae hatch and mature and a brood of mosquitoes gets on the wing.

Shortly after 1900 Dr. Smith began to experiment to determine the type of ditching that would cause the waters of the marsh to rise and fall with the tide and to afford access of the killifish to all parts of the marsh waters. After many trials he settled upon a ditch ten inches wide and thirty inches deep, with perpendicular, smooth sides, as the one most nearly fulfilling the requirements. This depth normally reaches the bottom of the sod and is maintained, except where a natural slope requires a deeper cut to insure the free flow of the water. As the upland is approached the sod and underlying mud become less than thirty inches deep and a sand or clay bottom appears. The ditches are allowed to become shallow as the sod gets thinner. Neither sand nor clay subsoil is cut into except as the drainage of a pool or area behind the barrier requires such action. More recently it has been found that where the water is comparatively low in saline content, as along the course of rivers and the sections of bays adjacent to their mouths, the cutting of a thirty-inch ditch is followed by the washing out of underlying mud, causing the ditch banks to soften and the ditches to start development as natural marsh guts. It has been found also that in such places such undesirable results are largely eliminated by cutting the ditches so shallow that they do not go below the matting of grass roots. In recent years it has been found that on most marshes ditches as shallow as twenty inches in depth will bring about sufficient circulation of tidal water and provide adequate drainage to prevent mosquito breeding. Accordingly most recently constructed ditches on the open salt marshes have been limited to depths of from twenty to twenty-four inches. This phenomenon of washing out of underlying soil and softening of ditch banks is also contributed to by the presence of a strong tidal suck. The effect of this tidal suck can be cut down by placing ditch boards at the opening of the ditches, the top of which is the height of the bottom of the ditch and by outletting insofar as possible these ditches into creeks and thoroughfares where the tide range is not so great.

Insofar as the nature of the marshes will permit, these ten-inch circle ditches are opened into the natural creeks that meander through them. When such drainage is impossible, large main ditches, as wide as may be necessary, are cut as outlets.

In cutting the ditches it is best to remove the sod in pieces ten inches wide, by six to eight or more inches thick, the length being equal to the depth of the ditch because these large pieces are heavy, not easily moved by the tide, and can be conveniently carted away by the landowners.

Much experience with the floating of sods taken from these ditches has been accumulated in the course of the last two decades. Whether the sod consists of pieces as described above or of long ribbons, sooner or later through loss of water they become light enough to float. When the marshes become covered deeply by tide these sods are lifted and carried hither and yon. Most of them seem to be carried toward the inner edge of the marshes and deposited, and others are carried out in the channels and bays. Eventually they become sufficiently water-soaked to sink to the bottom. In this way creeks and thorofares, especially the latter running through the marshes, become so choked in places that their navigation by motor boats has been greatly reduced. In some cases these sods have been carried to oyster beds, forming mud sills and causing the destruction of some oysters. It is obvious that no sods should be left on top of the marsh. Special machinery has been developed for the purpose of cutting these ditches, chewing up the sods and eliminating the sod problem.

In every area ditched thus far, small shallow pools have been found which do not drain readily into the neighboring ditches and which are too small to merit drainage by means of a spur. Such holes are filled with sods from the ditches. After the sod filling has been thrown in, the surface of the rough pile is broken up and smoothed off. In a few years the grass grows over the fill, obliterating the hole.

The past two decades have witnessed some very important changes in trenching the salt marsh for mosquito control. It has been clearly shown during that period that no salt marsh is so well ditched that it will at all times be free from mosquito breeding, except the large permanent pools which are always well stocked with killifish. There are times when, because of high tides, continued rain and cloudy weather, the water derived from high tide or heavy rainfall or from both fails to be drawn off in time to prevent the maturing of the last remnant of the brood. Moreover, it may be said that the ditch mouths become plugged with sand or seaweed through the action of the waves and that by one means or another ditches farther up in their courses become plugged with pieces of sod, accumulations of hay, and other rubbish. All of which proves the need to patrol the ditched salt marshes throughout the mosquito breeding season.

It can be said, however, that during this period no case has come to the author's knowledge in which the ten-inch wide trenching of the ordinary high-lying salt marsh has failed to eliminate all but a small percentage of the brood which started.

The great differences of opinion as to the amount of trenching necessary to free an acre of breeding salt marsh from danger are due to the different kinds of salt marshes.

Marshes filled with holes and depressions require more extensive ditching than others. Some marshes are protected from the tide by dikes, and the natural drainage water is removed by tide sluices or even by pumps. These require a larger amount of drainage, the extra amount being necessary in cutting outlets for the primary system. It seems probable that between 200 and 300 feet of ten by thirty-inch ditching is the average. To this must be added an amount of hole filling and shallow spurring which will add about ten per cent to the acre cost. Fortunately, large portions of the salt marsh, particularly in the southern part of the state, are so low-lying and open to the tide as to be swept by every tide which is a little higher than the ordinary, and are on that account so free from breeding as to require no ditching. In a given area which includes a considerable amount of this kind of land, the required number of feet of ditching per acre will be materially reduced.

The plan of trenching has not undergone marked changes. By 1912 two general plans were in use, the first of which might be called the parallel system, and the second, the pool-connecting system. In the parallel ditching scheme more generally used the territory to be ditched was divided into districts on the basis of the possible outlets and each block of territory crossed by parallel ditches, lying sufficiently close to remove the surface water. Holes and depressions were spurred into these parallel ditches or filled with sod or other material. In the hole-connecting scheme ditches were run from one hole to another and finally into one or more outlets. It was held that such a plan was most practicable where the marshes were very full of salt holes. Experience since that time has clearly indicated the superiority of the parallel ditching, and the hole-connecting plan has been practically abandoned.

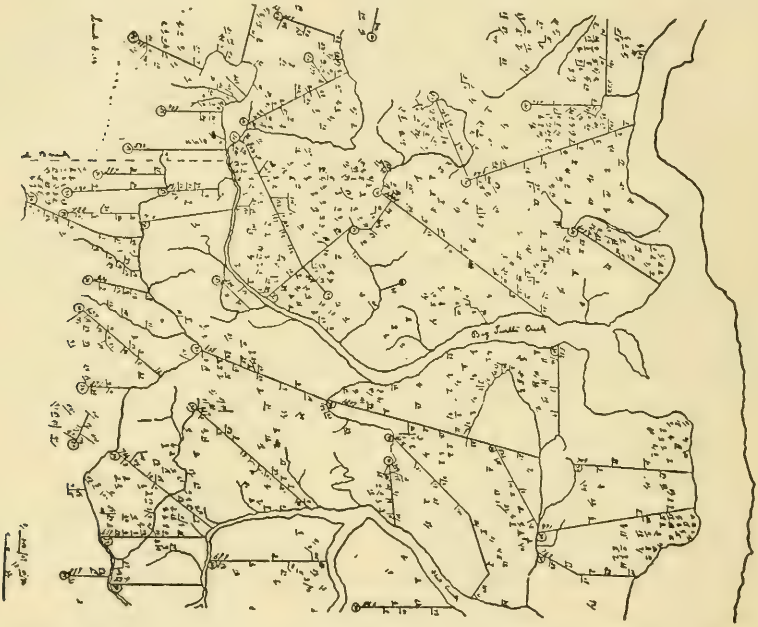

Fig. lxxxiv. Map showing hole-connecting scheme of ditching.

Since 1912 Eugene Winship, of the New York City Department of Health, has devised and caused to be installed a large amount of a still different system of salt marsh drainage. It is known as the "Checker Board System" and consists essentially of two parallel systems one superimposed at approximately right angles to the other. Mr. Winship claimed that with so many outlets it is practically impossible for the drainage of one area to become blocked and that the maintenance problem is therefore less difficult. This system has not found favor in New Jersey for three reasons: (1) the cost of the system is much greater; (2) on the meadows treated in this way, the ditches interfere with the use of equipment employed in harvesting hay; (3) mosquitoes are not materially reduced.

Early in the ditching program it was recognized that the type of outlet was of supreme importance, and recent experience has served to confirm this notion. The greater the tide drop and the shorter the ditch the greater is its efficiency and its ability to keep clean. Every ditch should have a strong tidal outlet and no ditch depending on a single outlet should be over one-fourth of a mile long.

MACHINERY

While the hand tools have made little if any advance, the Manahan, Skinner, and Eaton spades being still prevalent, power machinery used in cutting ditches has undergone some important changes.

The power machine invented by Mr. Eaton has been replaced by a power ditcher designed by Fred A. Reiley. Both the Eaton and the Reiley ditcher consist of separate power and plow units. The Eaton plan required first the movement of the power plant from point to point and then the dragging of the plow across the marsh to the new location of the power plant. The Reiley plan includes the attachment of the plow to a mobile power plant which pulls the plow cutting the ditch as it goes. The original Eaton ditching plow has been greatly modified and improved by Mr. Reiley. In both cases the sod was cut from the meadow and deposited on one or both sides of the ditch, ready to dry up and float about with the high tides.

Realizing the very serious disadvantage of these sods the New Jersey State Agricultural Experiment Station has developed a salt marsh ditch-cutting machine which cuts the trench for at least as low a figure as the Eaton or Reiley machines for from one-half to one cent a linear foot, and which grinds up the sod and disperses it on the marsh surfaces in the form of mud in a layer so thin that the grass readily grows up through it and no floating takes place.

MAINTENANCE OF SALT MARSH DITCHING

There is now about 38,000,000 linear feet of ditching, reckoned in units ten inches wide, on the New Jersey salt marsh. Experience shows that on an average these ditches have to have blockages removed annually and to be recut once in three years. Blockage removal is inexpensive and quite within the means of the mosquito commissions but the problem of proper recutting is greater. In a county having 12,000,000 linear feet of salt marsh ditching, 4,000,000 linear feet would have to be recut yearly. Recutting this amount with present machine equipment means an expenditure of about $20,000. The largest annual appropriation ever received by this county commission was $60,000.

The New Jersey State Agricultural Experiment Station is developing a salt marsh ditch recutter designed to recut at one-tenth of a cent a linear foot. This development is already well along and when completed can shrink the $20,000 figure to $4,000, thus immediately becoming very practicable. Furthermore, it is believed that the same machine will be able to cut new ditches at as low a cost as any other machine thus far developed.

Ditches on the salt marsh forty inches or wider will have to be recut by hand or by small caterpillar dredges, unless new continuously-operating machinery is later developed. Fortunately, the amount of this type of recutting is but a very small percentage of the total.

TREATMENT OF THE ENCLOSED SALT MARSH

In some instances the drainage established by nature has been so interfered with by the activity of man in the building of railroads, roadways, dikes and banks, that reopening sufficiently wide outlets has become impracticable. Furthermore, this shutting in has in some cases so interfered with the vegetation that it has died and the marsh surface lowered in extreme cases as much as 3.5 feet. To make a bad matter worse, at many points the raw sewage from large populations has been emptied into these artificially formed basins.

The solution of the problem is to shut out the sea and remove such water as occurs behind the barrier either by gravity through sluices or with pumps. A considerable fund of experience is now available for the treatment of shut-in marshes that have and have not shrunken. About 6,000 acres have been thus completely treated for mosquito control.

The problem of the enclosed, nonshrunken and sewage free marsh is relatively simple because gravity furnishes all the power necessary to move the water.

Of course, the first step is the installation of internal ditching of the type used on the open marshes. Whether dikes are necessary in such an area depends on the height of the meadows adjacent to the tide. When the natural land is well above mean high tide, which is usually indicated by the presence of prolific growth of salt grass (*Spartina patens*) and the presence of rows of debris brought in by the extra high tides, there is good reason to believe that in most seasons a dike would prove a useless expense. In such cases it is merely necessary to install sluices and tide gates in the principal outlets and to block up the others, connecting them with the principal ones.

When the land bordering the tidal water is low, which is usually indicated by the presence of coarse grasses (mainly *Spartina alterniflora*) and the absence of lines of debris, or when the agency concerned wishes to provide against extreme tides, the portion of the area adjacent to tidal waters must be protected by a low dike and the water inside let out by sluices and tide gates.*

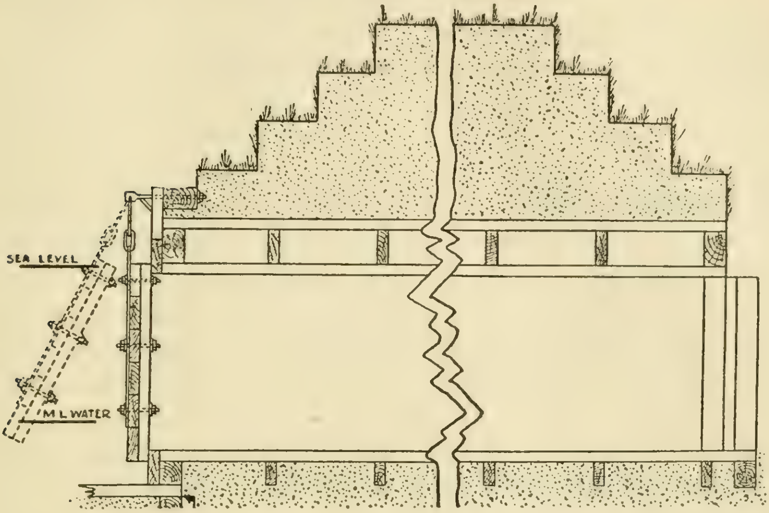

Fig. lxxxv. Diagram of sluice box and tide gate.

The height of the dike depends upon the height of the tide. In one case the dike was built to an elevation of seven feet above mean low tide, which was one half foot higher than the previously recorded highest tide for the season of 1914. The intention was to build it high enough to keep out all but the very highest of high tides, the theory being that these extraordinary high tides come so rarely and at such times of the year that fencing them out is unnecessary.

The early dikes as they were built stood three feet above the meadow surface, were two feet wide at the top and six feet wide at the bottom. Anticipating a shrinkage of about twenty-five per cent, the crest was made about one foot higher than the elevation called for. When the construction of the dike began, a trench ten inches wide by twenty inches deep was cut along the line to be occupied by the structure, and the sods taken out were utilized as part of the dike. A row of sods composed of pieces approximately ten inches wide, twelve inches thick, and twenty-six inches long was laid on each side of this trench with the grassy ends out, enclosing a space twenty inches wide. Mud was then tamped into the trench until its surface was flush with the upper surface of the sod layer. Then another layer of sod composed of pieces ten inches wide by twelve inches thick by twenty-four inches long was placed on top of each of the other two rows. Again the grassy ends were out but the ends of the upper layer were six inches nearer the dike center than were the ends of the lower layer. The central cavity thus formed was tamped full of mud. Then a third layer of sod was placed on the second in a similar fashion with a similar approach to the center. The space formed between the two parts of the layers was tamped full of mud. In some cases the dike thus constructed was covered with a layer of sod while in other cases the crest was simply rounded up with mud.

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* The questions of dike, sluice, and tide-gate construction for agricultural purposes have received a considerable amount of attention, and the facts have been pretty well covered in Bulletin 240 of the Office of Experiment Stations, U. S. Department of Agriculture, Washington, D. C., and reports of the State Geologist of New Jersey. The utilization of this construction for mosquito control is comparatively recent, but already it has been modified to serve the purpose better.

The sod and the mud for making the dike came from the preliminary trench and from a supply trench which was dug inside the protected area about eight feet from the base of the dike. In some cases a supply trench was dug on each side of the dike. In every case the supply trench was of uniform width, did not exceed three feet in depth, and was properly connected with adequate outlets.

During the summer the grass in the sods grew vigorously and transformed the dike into a wall of green. The sods used in capping the dike dried out and separated until they looked like the battlements of a wall, and the layer became useless as a means of keeping water out. The mud cap settled down and formed a continuous solid cap serving much better the purpose for which it was intended than did the sod layer.

Some dikes have been constructed entirely with mud, but always in places where sod was not available. In such instances the mud has been scooped from a trench back of the dike (forming a ditch paralleling the work and giving useful drainage), and piled up until a dike of requisite height with due allowance for shrinkage had been built. This was two feet wide at the top and as broad at the base as was demanded by the normal angle of repose. This type of dike does not withstand the weather or the water as well as the sod type, but is efficient if carefully looked after.

In more recent years many thousands of feet of dike have been constructed without any preliminary binding ditch, and it would seem in general to be as successful in fencing the sea water out as the dike of earlier construction. In certain sections of the Hackensack Valley the idea has arisen that the dike should be constructed without a binding ditch, but composed of sod containing the roots of the common foxtail (*Phragmites phragmites*). The experience has been that dikes thus constructed promptly show a rapid and vigorous growth of foxtail which serve to hold the soil of the dike together and give it much greater resistance to damage by the high tides.

In the construction of these dikes, at various points it is necessary to cross soft spots or deep soft ditches and thorofares. In such cases it has been customary to run a single row of heavy sheet piling across the mouth of the ditch and to bank the soil deeply on either side. In other cases two rows of sheet piling from six to twelve feet apart have been driven and the filling of mud has been tamped in between. More recently the foxtail weeds have been cut and laid in the mud crosswise, forming a mat over the soft spot or stream to be crossed. The soil is then thrown upon these reeds and tamped down, giving a crosswall without any other reinforcement. Thus far, this method seems to be fairly satisfactory in preserving the dike at such points.

At points where streams or larger ditches cross the dikes, sluice boxes and tide gates were introduced. The largest sluice box used measured inside four feet high, six feet wide, and twenty-four feet long. It was made of two-inch lumber nailed to outside ribs eighteen inches apart. The box was set on two rows of two-inch sheet piling and then covered with soil. A large heavy wooden door was suspended over the downstream end of the box to serve as a tide gate.

More recently some larger sluice boxes and tide gates have been constructed. Still more recently a proposition of using the same cross-section in the form of numerous small sluices and tide gates at the same spot has been tried. It is held that this last method is materially cheaper and at least equally as satisfactory as the larger sluices. Still another modification in tide gates has come into use. This is the use of galvanized corrugated iron pipe carrying a cast iron flap or gate. This sluice and gate is bedded on sheet piling and is rather extensively used. In general, the results seem to be about the same as the results of the wooden sluices.

In earlier practice along the Delaware Bay coast sluice boxes were made small and so deeply buried that at all times they were completely under water. In much of the mosquito work the sluice boxes have been set at a point where they are not continuously covered by water. There is no doubt in the writer's mind that the practice of setting the sluice box and gate so low that it is continually covered by water results in longer and better service, but the cost of the operation of setting sluices and tide gates this low is much greater.

Experience has clearly demonstrated that for all types of tide gates the piling must be driven well into the soil substratum for any movement whatever of the sheet piling seems likely to initiate the process of washing out. Not only must the piling fit but they must be very firmly bound together in single straight lines or they do not stand the strain.

The problem of preparing a proper dike, sluice boxes, and tide gates for draining a given area is an engineering one. Suffice it to say that the trenching, diking, sluicing, and tide gating must be so planned as to keep out all but the most extraordinary high tides and to free the surface from water within five days after a heavy rainfall.

The last step in the initial treatment of this type of marsh to prevent maturing of mosquitoes is the arrangement of the drainage system and the manipulation of the tide gates in such a fashion that tide water with its supply of killifish can be brought into the area and caused to circulate (without overflowing the ditches) throughout the system and again escape from the area. Experience has clearly shown that failure to provide for this circulation is followed by breeding in stagnant water in the ditches. This requires the extensive use of oil or larvicide which cannot usually be made sufficiently complete to prevent the emergence of all of the mosquitoes.

At this point the danger which marsh enclosure involves should be emphasized. If the brackish water is withdrawn from the marshes and kept off too continuously the salt grasses will die, their deep, penetrating roots will rot, the particles of soil will come closer together, and the surface of the marsh will lower to such an extent that removal of water by pumping may become necessary. If the gates are kept completely open from the first of November until the end of the following March, especially if the circulatory system above described is inaugurated, the strength of the salt grasses sod is not likely to be impaired.

The second type of salt marsh, enclosed, shrunken, but non-polluted basins, must either be covered with tidal water and schools of killifish, or the water removed by sluices and tide gates supplemented by pumps. Numerous examples of this type of enclosed marsh exist along the coast. The examples are usually where the marsh, which has been diked, sluiced and cultivated, has been allowed to fall into neglect. The dikes have been breached and the sluices have rotted away, and ordinary tide covers the land regularly. In such places no breeding occurs except along the edges of the highland where the mosquito breeding water is screened by aquatic vegetation from the fish.

When dikes have been erected to keep the sea out, sluices and tide gates will be found useful to remove the surplus water, lowering the water level to about one foot above mean low tide. Pumps must be installed to remove the balance because the surface is likely to be covered with pools after the utmost low water reached by gravity has been attained. Pumps of various types have been used, and thus far the low-head centrifugal kind has been most satisfactory. One twelve-inch pump of this type, with contributory ditching so arranged as to permit it to work at its limit of efficiency, has been sufficient to remove the surplus water from 1,000 acres. Such a pump cannot do this, however, unless the water is removed and a reservoir of surface soil from eight to twelve inches thick has been dried out before the mosquito season starts. With water at the marsh surface an extra heavy rainfall would so fill up the marsh that mosquitoes would probably escape before the water could be drawn off. This would be especially likely to occur when the rainy period is followed by cloudy weather, reducing evaporation to the minimum.

In dealing with marshes of this type, either provision must be made to bring in brackish water with its supply of killifish to be circulated through the ditches, or the ditches must be pumped dry and kept so. Flooding is probably the better plan because pumping is likely to be followed by the growth in the bottom of the drains creating blockages and eventually breeding places.

ENCLOSED SHRUNKEN AND SEWAGE-POLLUTED SALT MARSH

The third type of marsh, enclosed, shrunken, and polluted, must be enclosed to keep the sea out, must be pumped dry, and the sewage channels from the highland diked so as to prevent the escape of sewage waters from these channels into the marsh. Drainage, pumping, and the circulation of sea water must be provided as in the case of the enclosed shrunken and sewage free marshes. Of course, at the beginning, on any portion of such marsh, breeding may be more or less troublesome in the ditches but after the circulatory system has been at work for a period of time breeding will be as well taken care of as in the enclosed shrunken and sewage free marsh.

UPLAND MOSQUITO PROBLEMS

Although the upland is never entirely covered with water, there are besides occasional permanent pools, swamps, and streams the homes and business houses of hundreds of thousands of people, involving water containers of all sorts, artificial ponds and pools, house roofs, rain gutters, rain pipe leaders, cisterns, cesspools, storm sewers, sanitary sewers, and sewage disposal plants. Summer season rainfall greatly modifies this fundamental picture. When the rain comes in sufficient amounts within ten-day periods more than to compensate for evaporation, an enormous number of temporary pools and hitherto empty artificial containers become filled, an enormous increase in water available for mosquito breeding takes place. It is true that this heavy rainfall will wash breeding out of streams, storm drainage sewers and sanitary sewers but this fails to compensate for the enormous increase in temporary pools and the filling of artificial water containers.

CONTROL OF UPLAND MOSQUITOES

With this picture in mind we turn to the consideration of the control of the different groups of fresh water breeding mosquitoes. These groups are, in the order of their importance, the house mosquito group, the swamp mosquito group, the woodland pool mosquito group, and the malarial mosquito group.

The house mosquito group thrives in the wilds to some extent but is always found in breeding places created by man. The typical species (*Culex pipiens*) known as the house mosquito, has been called the "mosquito of civilization" because of its ability to thrive in breeding places created by man.

No water accumulation is too small and almost no water is too polluted with human wastes to breed house mosquitoes. In general *pipiens* is much more ubiquitous than *territans* and breeds in wider variety of water accumulations.

This group overwinters in the adult stage and consequently is greatly reduced in numbers by inclement weather. While normally these species do not show much migratory power, *pipiens*, when emerging from large breeding places in dense broods, has been proved to move at least two and one-half miles from the place of origin. Such movements are, however, believed to be extraordinary and to occur under special conditions only.

The problems in the control of the house mosquito group are concerned with finding breeding water about human habitations and promptly getting rid of it, or treating with larvicides to destroy all breeding in it. Sewer basins, cesspools, barrels, tubs, pails, and pans are expected breeding places but stopped up rain pipes, tin cans, crockery, furnace humidifiers, pools in cellars or under houses without cellars are often so hidden as not to be detected until emerging mosquitoes bring about a more thorough search.

It is significant that *Culex pipiens* is second in point of numbers in collections made in villages nearby great undrained salt marshes and in those sections of the state where the salt marsh mosquitoes are under control is definitely the dominant species. It appears to be more practicable to bring the salt marsh species under control than it is to get the best of the house mosquito. The reason for this condition lies in the nature and location of the breeding places of the two groups. The breeding of the salt marsh species occurs in the open away from human habitation and inspection reveals the conditions that must be met. The breeding of the house group occurs in water accumulations everywhere about, on and in human dwellings and places of business.

Thus far no scheme of inspection and treatment of the house mosquito group, which does not enlist the willing aid of the householder or factory manager, has been successful in securing and maintaining control.

The swamp mosquito group, consisting of *Aëdes vexans* and *Mansonia perturbans* pass the winter in the egg and larval stages respectively. The group breeds mainly but not entirely in the wilds. *Vexans* shows a great range of breeding places, ranging from the typical fresh water swamp through backyard lot pools to enclosed and low salinity salt marshes nor does it refuse to breed in water polluted with human wastes.

The *perturbans* habit of breeding only in permanent soft bottom pools and swamps, never rising to the surface for air, renders it immune to ordinary surface filming larvicidal applications.

The fresh water swamp group has considerable migratory ability. Movements of ten to fifteen miles are not uncommon but here as elsewhere it is the largest and densest broods that go farthest.

The removal of water by drainage, filling or impounding with bottoms dug to depth to prevent aquatic vegetation from growing in it and finally stocking these waters with wriggler-eating fish, will eliminate the breeding of both these species. Temporary treatments with larvicide will destroy *vexans* but, of course, will not reach *perturbans*. From Florida comes the suggestion that cutting off the tops of aquatic plants below the water surface destroys the perturbans larvae attached to their roots.

The woodland pool group, consisting of *Aëdes canadensis*, *Aëdes abfitchii*, *Aëdes trivittatus*, *Aëdes triseriatus*, and *Aëdes hirsuteron* pass the winter in the egg or egg and larval stages. This group breeds in the wild lands and ordinarily does not migrate to any considerable extent. So much of the woodland of northeastern New Jersey has been taken up for suburban homes that these comparatively nonmigratory species have been brought in sharp contact with human kind.

Contrary to all preceding species, except *perturbans*, the woodland pool group produces only one big brood a year. Hence, if the pools of an area are treated in the spring and breeding destroyed, further work against them is unnecessary for that season. Where blackening of the pool edges is not objectionable, heavily treating the pool edges with heavy petroleum oil in the winter or early spring serves to prevent breeding for considerable periods of time.

The malarial group, consisting of *Anopheles punctipennis* and *Anopheles quadrimaculatus*, pass the winter in the adult stage and the number of individuals is very greatly reduced by inclement weather. In general this group prefers to breed in clean water but will accept a considerable degree of pollution. No member of this group can be considered migratory but there is evidence to show normal movements greater than that which usually occurs with *pipiens*.

The distribution of *punctipennis* is general throughout the state while *quadrimaculatus* in considerable numbers appears sporadically. Areas having outbreaks of malaria have always shown unusual numbers of *quadrimaculatus*. On the other hand some areas having a high population of *quadrimaculatus* have shown no malaria. It seems that *An. quadrimaculatus* is a necessary link in the malarial chain while *An. punctipennis* is not. It also seems that *An. quadrimaculatus* function in malaria only when human carriers are present.

In controlling this group breeding water must be removed or impounded, rendered free from acquatic plant growth and stocked with wriggler-eating fish. Of course, temporary elimination can be secured by covering breeding waters with larvicide at regular intervals and killing the larvae.

The miscellaneous group consisting of some twenty species is comparatively rare and rarely sufficiently abundant to be considered of economic importance. Measures of control adapted to the natural habits of the species concerned must be adopted and put into practice. In general removal of breeding waters must be accomplished usually by drainage, or the breeding destroyed by covering the breeding water surface with larvicide.

STEPS IN MOSQUITO CONTROL

The procedure involved in bringing about the control of these groups involves first of all a knowledge of the composition of the mosquito fauna of the area to which protection is to be given because the size of the area which must be covered depends on the extent to which the mosquitoes occurring therein have extended flight habits.

The second step is the charting of all permanent mosquito breeding places contributing to the mosquito fauna characteristic of the protected district.

The third step is the provision of funds necessary to seek out and treat with oils and larvicides all mosquito breeding waters of both a permanent and temporary character and to accomplish such an amount of permanent removal of mosquito breeding waters that within a limited period of years this phase of the work may be brought to completion. The only limitation imposed upon funds for temporary treatment of mosquito breeding waters is concerned with those mosquito breeding waters, the permanent removal of which is provided for. The purpose of the temporary treatments with oil or larvicides is to afford the citizenry of the designated area protection against mosquitoes from the beginning of the project. The purpose of providing funds annually for elimination of a reasonable proportion of the permanent mosquito breeding waters is designed to start a process which will eventually render the increasing freedom demanded by the population possible of realization.

The fourth step is to form an organization to seek out during the mosquito breeding season on a regular weekly schedule all actual mosquito breeding occurring within the designated territory, to treat in such a fashion as may be practical all such breeding found before it has a chance to develop to adult mosquitoes. In addition the above organization must be so constructed that it can expand its activities in case of heavy rainfall to cover the thousands of temporary pools, created by this rainfall, and in which additional mosquitoes can develop.

The fifth step is to make intelligent use of mechanical gauges to measure the effectiveness of the work and to indicate where special effort should be focused.

Drainage is probably the most practical method of removing mosquito breeding waters from the upland. There are a few instances in which it is financially practicable to fill mosquito breeding pools. Such drainage is naturally devoted to permanent breeding places. Rarely is it practicable to use it on temporary breeding places. There is nothing new or novel about this drainage. It is simply opening outlets to ponds, pools, and swamps by which the water can be drawn away.

There will be many instances of permanent mosquito breeding places which for one reason or another are undesirable to drain. Such places should have their banks sharpened and their waters stocked with minnows of game fish. The purpose of sharpening the banks is to prevent aquatic plants from forming a screen behind which the wrigglers can develop without danger from the fish. There are many artificial pools created for the sake of beautification of private property. Such pools should be stocked with fish and the banks should be likewise sharpened for the purpose of enabling these fish to reach all parts of the pools and to consume the wrigglers as they hatch in the waters.

For temporary destruction of mosquito larvae the use of oils or larvicides is necessary. Oil has the disadvantage of injuring to a greater or less extent the appearance of the pools treated with it, because that fraction of petroleum oil known as fuel oil, which is the most practical to use for this purpose, has a burning action upon plants with which it comes into contact. There is also some danger of destroying fish and water fowl inhabiting the waters thus treated. Within recent years a larvicide consisting of pyrethrum extract dissolved in fuel oil, emulsified with a sulphated higher alcohol, mixed with water and sprayed upon the water surfaces has been developed. With this material a total of about six gallons of actual oil is required to cover one acre surface of water, as compared with about forty to fifty gallons of fuel oil, yet the poisonous quality to mosquito larvae is practically equal to that of oil. This is due to the toxic action of the pyrethrum extract upon mosquito larvae. This type of pyrethrum larvicide has no deleterious effect upon fish, nor upon water fowl, nor upon aquatic vegetation. The cost per gallon of the diluted larvicide is about one-half of the cost of fuel oil per gallon. The pyrethrum larvicide has the disadvantage, however, of lasting for a much shorter period than the fuel oil and cannot always and everywhere be used as a substitute for it. It was developed by the New Jersey Agricultural Experiment Station for the purpose of putting in the hands of the mosquito fighter a material which might be used on water surfaces where fish, aquatic plants or water fowl are an important consideration.

All species of mosquitoes are readily killed by these larvicidal applications except *Mansonia perturbans* which remains at the bottom of the soft-bottomed pools attached to the roots of aquatic plants throughout the larval stage. Surface larvicidal treatments cannot, therefore, be effective with this species. The larvicides that mix with water require great volume and are usually sufficiently poisonous to do harm to the aquatic plants and to fish. The only satisfactory way of handling the problem of *Mansonia perturbans* is to dig out the water plants growing in the infested pool or pond or section of the lake, so deepening the water that no aquatic plants can grow through, piling the debris thus obtained along the edge, building up the banks so that the descent from the upland to the water surface will be sharp, or by so lowering the water level that the breeding places of this species are uncovered and dry out.

8

LARVICIDES

A LARVICIDE FOR MOSQUITO CONTROL PURPOSES is material (usually a chemical compound) which when applied to water, where mosquito wrigglers are present, kills them. The ideal larvicide would be a material or a process that would kill mosquito larvae, be noninjurious to aquatic plants, fish and water fowl, with one application remain effective throughout at least one season, and be cheap enough to be practical over thousands of acres.

Let us see to what extent our present larvicides approach this ideal. Early in mosquito work it was discovered that kerosene applied to mosquito breeding water surfaces so as to form a film killed mosquito wrigglers. Dr. L. O. Howard's publication (13) of this fact had much to do in starting local mosquito control efforts in northeastern New Jersey, notably at South Orange under the leadership of Spencer Miller. Before long, larvicides of character miscible with water followed. As time passed, however, since petroleum oil was cheap, and required for its effect merely the establishment of a surface film, quite regardless of water depth, it became the accepted larvicide.

Studies were undertaken to develop petroleum blends, that would not only form a film quickly but also remain actively present for the greatest possible length of time. These two qualities were somewhat opposed to each other. The oil finally selected had to represent a compromise.

Efforts were made to increase the poisonous character of the film by the addition of highly toxic oil fractions. Incidentally studies of toxicity of petroleum oil fractions to mosquito larvae proved that the more unsaturated the oil the more toxic it was to the larvae. The wide range in time required to kill larvae ran from several hours with almost completely saturated oils to a few minutes (thirty or less) with highly unsaturated oils. The difference between saturated and unsaturated oils is briefly this. All petroleums are composed of hydrocarbons. If these hydrocarbon molecules have few or no free bonds, the oil is highly saturated; if they have many free bonds, the oil is considered largely unsaturated. The former is chemically inactive, the latter chemically active.

Saturated oils kill mosquito larvae largely by suffocation. Unsaturated oils kill the larvae by chemical attack on the protoplasm of the wriggler. Destructive effects of unsaturated oil are correspondingly greater to aquatic plants and other animals. In making up a set of specifications for an oil larvicide, therefore, the degree of saturation had to be taken into consideration.

For efficient mosquito eradication oil must possess the following properties:

1. It must kill larvae and pupae within a short time after application.
2. It must spread rapidly on the water surface in order to penetrate all the hiding places of the larvae and pupae.
3. It must produce a uniform, unbroken film on the surface so that no wriggler can escape it.
4. It must remain on the water for a comparatively long time in order to kill the newly hatched larvae and to prevent the adult mosquito from laying eggs.

Experiments conducted at the New Jersey Agricultural Experiment Station have shown that fractions of petroleum boiling at 200°–550°F. are very toxic to larvae and pupae, giving complete kill within thirty minutes. The higher boiling fractions possess lower toxicity, requiring several hours to kill, meanwhile allowing mature pupae to develop into adults. On the other hand, the low boiling fractions possess high volatility and rapidly evaporate from the surface of the water, whereas the high boiling fractions do not volatilize and only slowly decompose, leaving an oil film on the water for a long time, thus preventing oviposition and hatching of mosquito eggs.

A mixture of these fractions in proper portions produces an oil which is highly toxic to larvae and lasts for eight days or longer. An oil of the following specifications was found very efficient:

Type of Oil	*Distillate Fuel*
Specific gravity	27°–33° Be.
Flash point	130°F. (P.M.) or higher
Viscosity	35–40 S.U. (a) 100°F.
Odor	Sweet (non-offensive)
Distillation range, Degrees F	10 per cent—430–450 50 per cent—510–550 90 per cent—630 or higher

This oil can be readily prepared by mixing low grade kerosene, or a similar cheap light fuel oil, with various proportions of either heavy distillate fuel oil or crankcase waste oil. There are now on the market a number of light fuel oils which come close to the aforementioned specifications and are cheap enough to be used in mosquito extermination work.

The actual amount of oil required to produce a uniform killing film depends on the kind of oil used and the nature of the breeding place. A clear water surface will require less oil than a surface covered with vegetation, debris, and other materials which may offer resistance to the spreading of the oil. Generally, about forty to fifty gallons of oil per acre are required. On places thickly covered with vegetation, debris and sewage, the spreading of the oil may be hastened by mixing in certain chemicals. The addition of about 0.5 to 1.0 per cent cresylic acid or similar tar acids or small amounts of oleic acid, pine oil, turpentine, and similar compounds will materially aid in spreading the oil.

Long experience showed that such an oil, while efficient against mosquito larvae, was injurious to some aquatic plants and under certain favorable conditions, such as shallow water, damaged fish. Water fowl damage was occasionally claimed.

The problem was then attacked of how a low-priced larvicide could be made which would destroy mosquito larvae and at the same time reduce the amount of oil so as not to damage aquatic plants, fish and water fowl. Studies showed that the addition of the extract of 1 pound of pyrethrum flowers (analyzing 0.9 per cent pyrethrins or more) to a gallon of oil gives the necessary build-up in toxicity to mosquito larvae. The oil should, therefore, contain a minimum of 0.1 per cent actual pyrethrins. Of course, the pyrethrins when in colloidal solution in water are toxic to fish, but when dissolved in oil stay in the oil and cannot be drawn out of it by water.

Many formulae were tried on both fresh and salt water, and it developed that the soap emulsification, while it worked beautifully in fresh water was decomposed in salt water. To meet this situation, after powdered milk was tried, reference was had to Gardinol, and the following formula was adopted as the standard New Jersey Larvicide:

NEW FORMULA FOR TANK PREPARATION (STOCK SOLUTION)

100 gallons of kerosene containing enough pyrethrum extract to equal 100 pounds of flowers (containing at least 0.9 per cent pyrethrins)

6 pounds Gardinol W.A. concentrated
50 gallons of water

The Gardinol is first mixed with the water and transferred to the tank. The oil is run into the tank gradually with agitator and pump working at full speed. After all the oil is in, the pumping is continued until the entire mixture has passed through the hose and back into the tank two or three times or until the mixture is homogeneous, showing no free oil on the surface. Excessive foaming may be prevented when Gardinol is used by dissolving two or three pounds of wool grease (Degras) in the kerosene before adding to the water and Gardinol. The concentrated stock larvicide should contain a minimum of .07 per cent actual pyrethrins.

When it is ready to apply, ten parts of water are added to one part of stock emulsion, and it is agitated thoroughly. This diluted larvicide is then sprayed on a water surface the same as oil, a total of fifty to seventy gallons being applied to an acre of water surface. The per spray gallon cost of this material is about one-half the cost of the oil larvicide specified above. If the spray material has to be carried any considerable distance into a swamp or over a marsh, transportation costs of the larvicide are much less, for only the stock solution has to be transported, the necessary water for dilution being taken up at the point of treatment.

There are many permanent bodies of water, such as fire tanks, barrels, tubs, buckets, and vats in which mosquito breeding takes place, so located as to be difficult of access. Here a nonvolatile and long lasting larvicide is called for. Many chemicals qualify for this purpose, but iron sulphate or copper sulphate are most practical. The iron sulphate should be used at the rate of fifty parts to 1,000 parts of water and the copper sulphate at the rate of ten parts to 1,000 parts of water.

The ideal larvicide, therefore, has been closely approached in killing power, in cheapness, and in freedom from injury to aquatic plants, fish and water fowl, but it still falls far short of desired persistence.

NEW JERSEY LARVICIDE AS A PROTECTION FOR OUTDOOR EVENING GATHERINGS

From time to time for many years citizens of New Jersey have inquired for some method of protecting persons attending outdoor evening gatherings from the mosquito pest. These inquiries have come mostly from individuals contemplating staging outdoor evening parties, but also from associations and in one case from a "drive-in" movie theatre. Many materials were tried, including fly sprays, and only a mediocre success obtained. During the later stages of the development of the New Jersey larvicide it was given a trial and the results were at once attractive.

The tests began in 1930 and continued with increasing numbers through the years to 1935. At that time since it was desirable to obtain correlated figures, cooperating agencies, principally mosquito commissions, were requested to file reports covering the following points: description of location, size of area sprayed, type of sprayer used, dilution of larvicide, date and time of day applied, amount of diluted larvicide applied, species of mosquitoes present before spraying, frequency of biting before spraying, protection from biting after spraying, length of time protection lasted, number of people conducting the test, injury to vegetation, discomfort encountered by men, and discomfort encountered by women.

Some of the most significant results are shown on Table XI.

A detailed description (8) of an operation at the Newark Schools Stadium will be of interest in this connection:

"It may be of interest to describe here the following incident observed while applying the larvicide in the Newark Schools Stadium, the largest area ever treated (approximately sixteen acres), where four open air concerts were held. It occurred during the third concert, on the evening of July 2. Due to heavy rains during the previous week the Passaic Valley became flooded and was breeding heavily. We were warned by the Essex County Mosquito Commission to expect a heavy brood in the stadium. This prediction was substantiated by three mechanical traps stationed in nearby untreated localities. Some 200 female mosquitoes, mainly *A. vexans*, were caught in the traps during the evening. Observations on previous evenings disclosed that the mosquitoes were starting their flight from the marshes into the stadium grounds about 8:15 P.M. (daylight saving time), becoming very numerous at 8:50 P.M., and diminishing at 9:30 P.M. On the afternoon of July 2, many mosquitoes were found within the stadium in the grass, especially near the fences and under the bleachers. These became active when disturbed. At about 6 P.M. the entire area was thoroughly sprayed and the atmosphere fogged with larvicide diluted 1–10. A survey of the area was made at 7:30 P.M. by four inspectors, and not a single active mosquito could be detected. Since the mosquito flight was expected to take place with the wind, which was at that time blowing from the south, several inspectors were stationed on that side of the stadium in order to detect the beginning of the flight. Also, a 400 gallon 'Bean' sprayer (supplied by the

TABLE XI

Results with Different Sprayers

Description of Location	Size of Area Sprayed	Kind of Sprayer Used	Mosquito Density in Untreated Area Nearby	Protection from Mosquito Bites	No. of People Present
Open Air Concert Newark Schools Stadium, lawn in center about 6 acres, many shade trees within and around the stadium. 7–7–36.	About 16 Acres	Power Sprayer	Very heavy. 191 females in 3 traps. *A. vexans*	Practically complete for entire period of the concert.	18,000
Ball Game Warinanco Park, Elizabeth, stadium and athletic oval. 7–15–36.	About 7 Acres	Power Sprayer	3 bites per min. per person. *A. vexans*	Complete during entire evening.	8,000
Open Air Concert Green Brook Park, Plainfield. Natural amphitheatre in valley; trees, shrubs and grass. 7–2–36.	About 5 Acres	Power Sprayer	Night before unbearable as reported by Park police. *A. vexans*	About 95% during concert.	2,500
Running Track Concrete stand surrounded by shrubs, trees, near vacant lots. 7–8–36.	About 7 Acres	Power Sprayer	4 bites per min. per person. *A. vexans.*	Complete	7,000
School Play Ground Grass, Shrubs, trees; graduation exercises. 6–17–36	About 4 Acres	Power Sprayer	1 bite in 5 min. per person. *C. pipiens* *A. vexans*	Complete	1,000

Private Lawn Grass lawn surrounded by shrubs, shade trees; near meadows and woodland. 7–22–36.	75 x 50 feet	Hand Spray Pump	25 females in 1 trap *C. pipiens* *A. vexans* *A. sollicitans*	Almost complete for 3 hours, a few bites reported	5
Private Lawn Same as previous experiment. 8–11–36.	75 x 50 feet	Knapsack sprayer	22 females in 1 trap *C. pipiens* *A. vexans*	Good but not complete	6
Porch In front of house; surrounded by lawn, shrubs, near woodland. 7–25–36.	60 x 30 feet	Small electric sprayer	41 females in 1 trap *C. pipiens* *A. vexans* *A. sollicitans*	Complete with continuous fogging.	4
Porch In front of house; surrounded by lawn, shrubs, near woodland. 7–22–36.	60 x 30 feet	Hand spray pump	25 females in 1 trap *C. pipiens* *A. vexans* *A. sollicitans*	Complete for 2½ hours.	4
Porch In front of house; surrounded by lawn, shrubs, near woodland. 8–11–36.	60 x 30 feet	Centrifugal electric vaporizer	22 females in 1 trap *C. pipiens* *A. vexans*	Complete for 2 hours.	3

Newark Shade Tree Commission) was kept in readiness for spraying. Until 8:50 P.M. no mosquitoes were noticed flying in. Soon after, two inspectors reported that a number of mosquitoes were alighting on the audience and people were beginning to slap. Close observations disclosed that they were flying in with the wind from the south side, as anticipated, but too high for detection by the inspectors, since it was already getting dark. Apparently repelled by the larvicide fog which was settling low, the mosquitoes rose high above it. Then, attracted by the 15,000 persons gathered there, the insects descended into the center of the stadium. The area in the south section of the stadium was immediately fogged with larvicide from a shade-tree gun which threw a stream thirty to forty feet high against the wind. This produced a blanket mist of larvicide drifting with the wind, high above the audience and slowly settling downward. Within a few minutes after it was applied, the mosquitoes disappeared, and no further annoyance was encountered by the audience for the rest of the evening. At the same time the mosquitoes were very numerous outside of the stadium."

Dr. Ginsburg (8) presents his conclusions from his work on this subject as follows:

"Experiments with the New Jersey Pyrethrum Mosquito Larvicide conducted during three seasons, in protecting persons in all kinds of outdoor evening gatherings from mosquito bites, are described. Different types of sprays were tested. The results thus far obtained indicate that:

"1. Outdoor areas, such as picnic grounds, stadiums, lawns, and porches can be made practically mosquito-free without injury to vegetation and with no appreciable discomfort to people.

"2. On large areas, power sprayers capable of quickly supplying a fine fog, high in the air, are required.

"3. On small areas, such as lawns and porches, hand pump sprayers or small electric sprayers may be employed.

"4. On small porches, centrifugal electric vaporizers can be used, provided that the operation is continuous and produces a constant supply of larvicide mist."

According to Robert L. Vannote, a practical operator (29):

"The application of the repellent is perhaps the least complicated task of the entire operation. Expert knowledge is required to plan where, how, and when to make the application to ensure positive protection before and after dusk without interference or annoyance to the group.

"The three general fields of protection are the unscreened porch; the small yard not exceeding 2,500 square feet, with a limited number of high shrubs or trees; any area exceeding 2,500 square feet.

"In the case of the unscreened porch, control methods are simple. The larvicide, diluted 1–14, sprayed over the porch to kill mosquitoes already there, and then directed away from the porch, will set up a protected zone. The application must be repeated as mosquitoes appear in flight, particularly if the porch is not protected by shrubs or other vegetation from which the larvicide will slowly evaporate. A large hand sprayer or an electric vaporizer is sufficient equipment for the control of small areas.

"The schedule for yards and larger areas is more complicated. For convenience, it is divided into (1) examination and planning, and (2) the application of larvicides.

EXAMINATION

"A thorough survey should be made of the area twenty-four hours before application and the following items observed. When this information is available, the Director of Operations should prepare a plan which should contain enough detail to enable the spraying crew to complete the job without further instruction.

"1. *Size of area.* Determine the exact area to be protected. Insist on a free margin of approximately 100 feet wide around the area. Should the sponsoring agency neglect to provide such a margin, do not attempt control.

"2. *Other conditions to be noted*:
    "A. Source of mosquito annoyance and direction of migration.
    "B. Note extent of mosquito resting places, such as dense shrubs or woods.
    "C. Prevailing winds both before and after dusk.
    "D. Types of vegetation. Fine lawns, flowering plants, and tender shrubs must be noted.
    "E. Type and location of buildings.
    "F. Nature of activity or program. Types of clothing, effect of noise, time of intermissions, should be noted and spraying plans made accordingly.
    "G. Time activity is planned to start and stop.

"3. *Plan of action*:
    "A. Locate a central position for spraying equipment and open avenues of movement.

"B. Determine lengths and number of hose lines required.

"C. Locate available water supply. A fire hydrant or large size supply outlet is essential to avoid delay in filling tank.

"D. Estimate time required to spray the area completely before the arrival of guests.

"E. Approximate the dilution of larvicide required. This will depend on the density of mosquitoes at dusk. For severe infestations, a dilution of one part of emulsion to eleven parts of water is recommended. On all other occasions a dilution of 1–14 is satisfactory.

APPLICATION

"The following guide indicates the methods essential for the efficient application of the larvicide as a repellent.

"1. *Inside application*:

"A. Have the spraying equipment in position with all necessary supplies at a time to permit a complete coverage of the entire area before guests arrive.

"B. Compare weather conditions with those outlined in the plan of operation and make changes if required.

"C. Start spraying on the windward side of the area and, working from edge to edge, proceed to cover the entire area with a mist of larvicide. Particular note should be made to spray all trees, shrubs, sheds, and other mosquito hiding places. When this operation is complete, all mosquitoes in the area should have been killed. The fine white residue may be brushed off the grass and low shrubs if required.

"2. *Marginal band application.* After the inside or main area has been sprayed the marginal band must be treated. The spray should be directed away from the inside area both to kill and to drive all mosquitoes away. It is wise to apply more larvicide on the marginal band so that a repellent zone is set up completely around the inside or main area.

"When mosquitoes are not numerous on the wing during the daylight hours, such an application will provide protection for the entire evening when applied one to one and one-half hours before dusk.

"It is well for the director to mingle with the guests near the windward side of the area before and at dusk. At the first appearance of invading mosquitoes the sprayer should move across the windward side rapidly setting up a high, well vaporized fog in the marginal band which will repel all invading insects. The fog should then be maintained across the entire windward side at a more leisurely pace. After the flight ceases, mosquito annoyance in the area will be negligible for the balance of the evening.

"Care should be taken to be ready to move the spraying equipment at a moment's notice in the event the wind should shift while the dusk flight is in process.

EQUIPMENT

"For areas of less than 2,500 square feet a three or five gallon compressed air hand sprayer, such as the 'Hudson, Jr.,' will produce satisfactory results when equipped with a mist nozzle. For larger areas a high pressure spray pump capable of developing 300 to 600 pounds pressure, mounted on a light, fast truck, is advisable. Sufficient hose and mist guns should be available. If the pump can be operated from the power take-off of the truck much of the engine noise is avoided. The larvicide should be agitated continuously and not left in dilution for any length of time.

"Strict care should be exercised to avoid contact with the guests. Although it is often humorous to permit the mist to drift over the guests, it is entirely unnecessary and creates a bad impression.

"Limit the help to those absolutely necessary for the quick, efficient handling of the hose and guns. Three men, including the director and truck operator, are sufficient to control an area up to four acres under all normal conditions."

MACHINERY FOR DISTRIBUTING LARVICIDES

The objective sought in the distribution of larvicide, whether oil or the New Jersey Larvicide, is the establishment of a killing film over waters in which mosquito wrigglers are developing. When the larvicide is delivered as a finely divided spray, it effects this cover most quickly and satisfactorily.

Delivery through a small-holed nozzle under high pressure or atomization seems to accomplish this fine division. The fineness of division in the first instance is the result of finding the proper relation between size of nozzle hole and pressure under which the liquid is forced out. Small holes are required when low pressure is used and the area-covering capacity of the machine is correspondingly limited. With high pressures (300 to 600 pounds per square inch) the nozzle hole can be much larger, and the area-covering capacity is consequently increased. The fineness of division in the second instance (atomization) is dependent upon the relation of the speed of liquid delivery to pressure of the air stream. If the rate of liquid flow is increased and air stream pressure remains the same, the division will be coarser, while if the rate is decreased the divisions will be finer. Likewise taking the rate of liquid delivery as constant, increase in pressure of the air stream means fine division, while decrease in pressure of the air stream means coarser division.

Larvicide may be distributed from the ground by small sprayers or by powerful truck sprayers. Employment of the first type means much man labor while use of the latter means a comparatively small amount of more highly trained labor. Larvicides may be distributed from the air by airplanes or autogiros. Here the larvicide is thrown in the slip stream of the propeller. When the delivering machinery is adjusted to give the proper amount of liquid to the slip stream, a very satisfactory atomization takes place.

In view of the small load an air machine can carry, it is necessary to use as concentrated material as possible. It has been found that eight gallons of oil per acre impregnated with about one ounce twentyfold extract of pyrethrum flowers per gallon of oil gives a killing film on water surfaces.

Thus far it has not been possible to distribute New Jersey Larvicide from airplanes with uniformly successful results. This seems to be due to a failure to obtain uniform and adequate coverage.

9

MOSQUITO REPELLENTS

As stated elsewhere, the outstanding vulnerability of the larva has largely prevented practical workers in mosquito control from attempting to use methods against other stages. The same factor has probably been instrumental in minimizing research designed to use other stages for practical control operations.

There was a long period of time, however, when the only attack made by mankind on the mosquito was devoted to repelling and destroying the adults. History shows that smokes of various kinds have been used to keep mosquitoes away. Various ointments, particularly of an oily, greasy character, have been applied to the human skin to prevent mosquitoes from biting. So we come down to recent times and find ground pyrethrum, otherwise known as insect powder, petroleum oil and various essential oils, recommended for preventing mosquitoes from biting the humans.*

Mosquito repellents are of two kinds. The first, a mixture of pyrethrins, petroleum oil, emulsifier, and water, is used to spray limited areas to destroy all the adults present and keep the invaders out. The second is some volatile material which, if during the period of its activity is applied to the human skin, prevents the mosquitoes from alighting and biting.

The development of repellent mixtures for the treatment of the human skin to prevent mosquitoes from alighting and biting has shown enough progress to justify a brief account of this work and its results. In the year 1935 Mr. George C. Furness, representing the National Carbon Company, approached the author on the subject of a grantin-aid designed to develop a better mosquito repellent. In view of the extensive development of synthetic organic materials, this seemed a good opportunity to attack the problem from the point of view of the relation of chemical structure and physical properties to mosquito repellency. Accordingly, a fellowship was established at Rutgers University and has continued up to the present time.

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* A brief but comprehensive sketch of this matter occurs on pages 365–367, Volume 1 of *The Mosquitoes of North and Central America and the West Indies,* by Howard, Dyar, and Knab. Even as late as 1939, Dr. F. C. Bishopp, writing in Leaflet No. 186 of the *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture,* summarizes the repellent situation as follows: "There is no known substance that will give complete freedom from mosquito attack for more than a few hours. Oil of citronella is probably the most dependable. If oil of citronella is objectionable because of its odor, it can be mixed with spirits of camphor or oil of pennyroyal in equal proportions. Certain cut or growing plants have been reported to drive mosquitoes away, but none of these is of practical value."

The first step was to determine the relation of chemical structure to repellency. The second was to study the relation of volatility to practical weather conditions, with special reference to temperature. The third step was to select the molecule of high repellency to mosquitoes, which at the same time is a molecule having the ability to volatilize under practical conditions repellent vapors over the longest possible period of time. The fourth step was concerned with the evaluation of repellent and toxic properties of the selected molecule when applied to the human skin in quantities sufficient to produce mosquito repellency. Step one would qualify a large number of compounds, step two would qualify far less, step three would qualify still less, and step four further reduces the number.

The first successful compound was a mixture of diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether, ethyl alcohol, corn oil, and perfume, later known under the trade name of "Sta-Way Insect Repellent." After a long period this compound was put on the market and immediately met with public favor. Then came the war and the search for mosquito repellents was intensified. The U. S. Bureau of Entomology and Plant Quarantine was charged with the duty of evaluating the worth of mosquito repellents already on the market and any other likely materials on which it could lay its hands. The laboratory at Orlando, Florida, was staffed and charged with the duty of carrying on this work. The fellowship laboratories selected from among their repellency compounds many of the more promising and submitted them to the Orlando laboratory for testing. Out of this testing an unusually powerful repellent, safe for human use, was evolved. The material is ethyl hexanediol, otherwise known as National Carbon 612. In the meantime, two other insect repellents were qualified by the Orlando laboratory. One is known as dimethyl phthalate, a compound which had been patented as an insect repellent. This quality of insect repellency of the phthalates was first uncovered as a result of fellowship work at Rutgers University sponsored by Stanco, Incorporated, from 1926 to 1934. The second is butyl mesityl oxide oxalate, otherwise known as Indalone, developed by the Kilgore Development Corporation. Subsequently the Bureau of Entomology and Plant Quarantine tested a mixture of these three repellents using six parts of dimethyl phthalate, two parts of National Carbon 612 and two parts of Indalone. This was said to possess synergistic qualities and to protect for a wider range of insects than the individual ingredients. It has been patented by the U. S. Bureau of Entomology and Plant Quarantine. It can be said that mosquito repellents designed to keep mosquitoes from alighting and biting have been developed to the point where their usefulness is unquestioned. The aspect of protection by area treatment is well developed and has had extensive practical test.

10

LAWS RELATING TO MOSQUITO CONTROL

THE FIRST LEGAL ENACTMENT was known as Chapter 98, Laws of 1902, under the terms of which the New Jersey Agricultural Experiment Station was charged with the duty of making a study and reporting on the nature of the mosquito problem of this state. The text of this act follows:

CHAPTER 98, LAWS OF 1902

An act to provide for an investigation and report by the New Jersey Agricultural Experiment Station upon the mosquito problem in its relation to the sanitary, agricultural, and other interests of the state.

BE IT ENACTED by the Senate and General Assembly of the State of New Jersey:

1. The New Jersey Agricultural Experiment Station be and the same is hereby empowered and directed to investigate and report upon the mosquitoes occurring within the state, their habits, life history, breeding places, relation to malarial, and other diseases, the injury caused by them to the agricultural, sanitary, and other interests of the state, their natural enemies, and the best methods of lessening, controlling or otherwise diminishing the numbers, injury or detrimental effect upon the agricultural, sanitary, and other interests of the state.

2. The sum of $10,000 is hereby appropriated to the New Jersey Agricultural Experiment Station to be applied to and expended for the purpose mentioned in section 1 of this act; such expenditures to be made and accounted for in the same manner as are the other moneys appropriated to said station.

3. This act shall take effect immediately.

Approved April 3, 1902.

Under the terms of Chapter 98, Laws of 1902, Dr. John B. Smith prepared and published his monumental work on "The Mosquitoes Occurring within the State, Their Habits, Life History, etc."

With the publication of this report the question of how to apply these findings arose but it was evidently the feeling of the workers at that time that local interest and effort should be incorporated and accordingly Chapter 80, Laws of 1905 was written in the statutes. The text of this statute follows:

CHAPTER 80, LAWS OF 1905

An Act to provide a method for locating and destroying mosquito-breeding areas, authorizing appropriations for said purposes and providing state aid for freeing salt marsh areas from mosquitoes.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. It shall be lawful for the mayor, or executive officer, or the board of health of any city, borough, incorporated town, village, or the government body or board of health of any township or county to make request in writing to the director of the Agricultural Experiment Station in this state, or to the person appointed by said director for the purposes of this act, to investigate, or cause to be investigated, the source of breeding places of mosquitoes which may or do infest said city, borough, incorporated town, village, township or county; and it shall be the duty of such director, or the person appointed by him, as soon as may be after such application is made, to innvestigate, or cause to be investigated, the source or breeding places of such mosquitoes, and he shall, as soon thereafter as possible, report to the officer or body making such application the results of the investigation made, and also the measures that should be adopted to destroy such breeding places or render them free from future mosquito breeding.

2. If such investigation shows that the sources or breeding places of the mosquitoes complained of are wholly within the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, a report shall be made to the officer or body requesting the investigation, and if such request does not come from a board of health, a copy shall also be forwarded to the board of health of such applying city, borough, incorporated town, village, township or county, which report shall specify in such detail as is possible such breeding places as may be abolished by such board under the powers conferred upon it by the laws relating to such board; if the investigation shows that the mosquitoes complained of breed wholly or in part at a point or points without the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, a copy of the report showing this result shall also be sent to the board of boards of health in the jurisdiction or jurisdictions where such breeding places are found, or if there be no organized board of health in any such jurisdiction, then the copy shall be sent to the mayor or executive officer of said city, borough, incorporated town, village, or the governing body of such township or county; the copy of the report above provided for, when sent to any officer, board of governing body or any jurisdiction other than the one from which the request for the investigation originated, shall be

accompanied by a statement giving the origin of the request, the reasons leading to the conclusion that the breeding places for mosquitoes lying within the jurisdiction to which the report is sent, are supplying specimens found in the neighboring jurisdiction, and submitting the measures that should be taken to abolish these breeding places.

3. Whenever an investigation made as aforesaid shall disclose the fact that the mosquitoes infesting the community and causing the nuisance complained of are those breeding on the salt-marsh areas within the jurisdiction of any city, borough, incorporated town, village, township, or county from which the application is made or adjacent thereto, a copy of the report shall be sent to the board or boards of health of the municipality or municipalities in which the breeding places are situated, attaching statements specifying the localities affected by the marsh-breeding areas, the extent of the dangerous area, the character of the work necessary to prevent further mosquito breeding, and the probable cost of the work required in each municipality. It shall be lawful for the governing body of any municipality above mentioned, upon the written request of the board of health of said municipality, to appropriate, in the same manner as other appropriations are made, seventy-five per cent of the sum required to complete the work aforesaid; whenever such appropriation is made and is available, said board of health shall certify this fact to the directory of the Agricultural Experiment Station, who may, out of the money appropriated by the state for this purpose, together with the appropriation of such municipality so certified as available, complete the work; provided, not more than $500.00 from said state-aid appropriation shall be expended in any one municipality in any one year.

4. Whenever it appears from the report made to any officer or body making application for an investigation, that the sources or breeding places of the mosquitoes complained of are on the salt marshes, wholly or in part without the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, it shall, nevertheless, be lawful for the governing body of any such municipality to appropriate in the same manner as other appropriations are made, such sum or sums as may be deemed necessary to assist the municipality in which the breeding places actually occur in securing the amount necessary to obtain the state aid conditioned in section 3 of this act; provided, that no matter how many municipalities contribute, the sum limited in section 3 shall not be exceeded in any one municipality.

5. All sums contributed or appropriated under authority of this act shall be paid to the treasurer of the municipality in which the work is to be done, and the funds shall not be deemed available until the entire amount contributed or appropriated shall be actually in the hands of such treasurer; payments shall be made by such treasurer in the same manner as other bills against the municipality are paid, but no bill for work done shall be paid unless it is accompanied by a certificate from the director of the Agricultural

Experiment Station or the person designated by him to carry out the purposes of this act, stating that the work is satisfactory and effective for the purpose intended.

6. The sum of $2,500.00 is hereby appropriated to the Agricultural Experiment Station for the fiscal year ending October 31, 1905 and the sum of $3,500.00 is hereby appropriated to said station for the fiscal year ending October 31, 1906, to defray the cost of executing this law and of making such investigations and experiments as may be necessary to carry out its intent and purpose, and the further sum of $10,000.00, $4,000.00 to become available during the fiscal year ending October 31, 1905, and $6,000.00 for the fiscal year ending October 31, 1906, or so much thereof as is needed, is hereby appropriated to said station to be used in carrying out the provisions for state aid.

7. This act shall take effect immediately.

Approved March 31, 1905.

Under the terms of this statute cooperation and state aid was to a limited extent offered to local legal bodies. Not enough educational effort had, however, been used to inform successfully the people of New Jersey on the nature and worthwhileness of attacking this problem in a practical way and the local response was correspondingly small.

It seemed necessary to the workers in those days that the only way to get action upon the discoveries brought forth in Dr. Smith's publication and to begin the freeing of the state from the mosquito pest lay in the assumption of the work itself by the state through the agency of its State Agricultural Experiment Station. Accordingly, Chapter 134, Laws of 1906 was written into the statute books. The text of this statute follows:

CHAPTER 134, LAWS OF 1906

An Act to provide for locating and abolishing mosquito-breeding salt marsh areas, within the state, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. It shall be the duty of the Director of the State Experiment Station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed all the salt marsh areas within the state, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section so surveyed, and shall indicate thereon all the mosquito breeding places found on every such area, together with a memorandum of the method to be adopted in dealing with such mosquito breeding places, and the probable cost of abolishing the same.

2. It shall be the further duty of said director, in the manner above described, to survey at the request of the board of health of any city, town, township, borough or village within the state, to such extent as may be necessary, any fresh-water swamp or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board, and he shall prepare a map of such suspected area, locating upon it such mosquito breeding places as may be discovered and shall report upon the same as hereinafter provided in section 8 of this act. Requests as hereinafter provided for in this section may be made by any board of health within the state, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

3. Whenever, in the course of a survey made as prescribed in section 1 of this act, it is found that within the limits of any city, town, township, borough or village, there exist points or places where salt marsh mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify, in writing, by personal service upon some officer or member thereof, the board of health within whose jurisdiction such breeding places or points occur, of the extent and location of such breeding places, and such notice shall be accompanied by a copy of a map prepared as prescribed in section 1, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, within twenty days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that under chapter 68 of the laws of 1887, as amended in chapter 119, of the laws of 1904, any water in which mosquito larvae breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito breeding pools, be abated within a period to be stated, and which shall not be more than sixty days from the date of such notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

4. In any case if any owner of salt marsh lands on which mosquito breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board to proceed to abate under the powers given in section 13 and 14 of the act and its amendments cited in the preceding section, or, in case this is deemed inexpedient, it shall certify to the common council or other governing body of the city, town, township, borough, or village, the facts that such an order has been made and that it has not been complied with, and it shall request such council or other govern-

ing body to provide the money necessary to enable the board to abate such nuisance, in the manner provided by law. It shall thereupon become the duty of such governing body to act upon such certificate at its next meeting and to consider the appropriation of the money necessary to abate the nuisance so certified. If it be decided that the municipality has no money available for such purpose, such decision shall be transmitted to the board of health making the certificate, which said board shall thereupon communicate such decision forthwith to the director of the Agricultural Experiment Station or his executive officer.

5. If, in the judgment of the director aforesaid, public interests, will be served thereby, he may set aside out of the moneys appropriated by this act such an amount as may be necessary to abate the nuisance found existing and to abolish the mosquito breeding places found in the municipality which has declared itself without funds available as prescribed in the preceding section. Notice that such amount has been set aside as above described shall be given to the board of health within whose jurisdiction such mosquito breeding places are situated, and said board shall thereupon appoint some person designated by said director or his executive officer a special inspector of said board for the sole purpose of acting in his behalf in abating the nuisance found to be existing, and all acts and work done to abate such nuisances and to abolish such breeding places shall be done in the name of and on behalf of such board of health.

6. If, in the proceeding taken under section 4 of this act, the common council or other governing body of any municipality appropriate to the extent of fifty per centum or more of the money required to abate the nuisance and to abolish the mosquito breeding places within its jurisdiction, it shall become the duty of said director of the Agricultural Experiment Station to set aside out of the moneys herein appropriated such sum as may be necessary to complete the work, and in all cases preference shall be given, in the assignment of moneys herein appropriated, to those municipalities that contribute to the work and in the order of the percentage which they contribute; those contributing the highest percentage to be in all cases preferred in order.

7. In all cases where a municipality contributes fifty per centum or more of the estimated cost of abolishing the breeding places for salt marsh mosquitoes within its jurisdiction, the work may be done by the municipality as other work is done under its direction, and the amount set aside as provided in section 6 may be paid to the treasurer or other disbursing officer of such municipality for use in completing work; but no payment shall be made to such treasurer or other disbursing officer until the amount appropriated by the municipality has been actually expended, nor until a certificate has been filed by the director of his executive officer stating that the work already done is satisfactory and sufficient to obtain the desired result, and that the arrange-

ments made for its completion are proper and can be carried out for the sum awarded.

8. In all investigations made under section 2 of this act, the report to be made to the board of health requesting the survey shall state what mosquitoes were found in the territory complained of, whether they are local breeders or migrants from other points, and in the case of migrants, their probable source, whether the territory in question is dangerous or a nuisance because of mosquito breeding, the character of the work necessary to abate such nuisance and abolish the breeding places, and the probable cost of the work. Said board of health must then proceed to abolish the breeding places found under the general powers of such boards, but if it shall appear that the necessary cost of the work shall equal or exceed the value of the land without increasing its taxable value, such board may apply to the director aforesaid, who may, if he deems the matter of sufficient public interest, contribute to the cost of the necessary work provided that not more than fifty per centum of the amount shall be contributed in any case and not more than $500.00 in any one municipality.

9. All moneys contributed or set aside out of the amount appropriated in this act by the director of the Agricultural Experiment Station in accordance with its provision shall be paid out by the comptroller of the state upon the certificate of said director that all the conditions and requirements of this act have been complied with, and in the case provided for in section 5 payments shall be made to the contractor upon a statement by the person in charge of the work, as therein prescribed, attested by said director, showing the amount due and that the work has been completed in accordance with the specifications of his contract.

10. For the purpose of carrying into effect the provisions of this act, the said director of the State Agricultural Experiment Station shall have power to expend such amount of money, annually, as may be appropriated by the Legislature; provided, that the aggregate sum appropriated for the purposes of this act shall not exceed $350,000.00. The comptroller of the state shall draw his warrant in payment of all bills approved by the director of the State Experiment Station, and the treasurer of the state shall pay all warrants so drawn to the extent of the amount appropriated by the Legislature.

11. This act shall take effect November 1, 1906.

Approved April 20, 1906.

Under the terms of this act the director of the Experiment Station was authorized to make surveys, plans and to expend moneys for mosquito control on mosquito breeding marshes. The work proceeded along this line until the year 1912. During this interim from 1906 to 1912, inclusive, educational processes in mosquito control had been assiduously prosecuted in this state and the feeling of various local associations was to the effect that local moneys should be provided for mosquito control. Doubtless the feeling that such procedure was advisable had its basis in the fact that the moneys appropriated by the state for such purpose had always been too small to accomplish it.

In accordance with this feeling Chapter 104, Laws of 1912 was written into the statute books.

Under the terms of this act the appointment of county mosquito extermination commissions was authorized for each county. These county commissions were given the power to do and perform that which is necessary for mosquito control. They were authorized to call for a limited amount of tax money but provision was made for co-ordination and control of their activities by a central agency, the director of the New Jersey State Agricultural Experiment Station, who was made ex officio member of each mosquito commission and who was charged with the duty of passing upon plans and estimates furnished by the county mosquito commissions and whose recommendation was made necessary to secure funds from the county fiscal organization for this purpose. The text of Chapter 104, Laws of 1912 follows:

CHAPTER 104, LAWS OF 1912

An Act for the establishment of county mosquito extermination commissions and to define their powers and duties.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. In any county of this state it shall be the duty of the justice of the Supreme Court presiding over the courts of said county to appoint six persons, three of whom must be persons who are or have been members or employees of boards of health. A board of commissioners to be known as "The ——— County Mosquito Extermination Commission," inserting the name of the county in and for which the commissioners are appointed. The commissioners first appointed under the provisions of this act in any county shall hold office respectively for the term of one, two and three years, as indicated and fixed in the order of appointment and all such commissioners, after the first appointment, shall be so appointed for the full term of three years; vacancies in the said commission occurring by resignation or otherwise shall be filled by such justice, and the persons appointed to fill such vacancies shall be appointed for the unexpired term only; such persons so appointed, when duly qualified, constituting such commission and their successors are hereby created a body politic, with power to sue and be sued, to use a common seal and make bylaws: the members of any such commission shall serve without compensation, except that the necessary expenses of each commissioner for actual attendance on meetings of said commission shall be allowed and paid. No persons employed by the said commission shall be a member thereof; before entering upon the duties of his office each commissioner shall take and

subscribe an oath or affirmation before the clerk of the county in and for which he is appointed, to faithfully and impartially perform the duties of his office, which oath or affirmation shall be filed with the clerk of the county wherein the commission of which he is a member is appointed; every such commission shall annually choose from among its members a president and treasurer, and appoint a clerk or secretary and such other officers and employees as it may deem necessary to carry out the purposes of this act; it may also determine the duties and compensation of such employees and make all rules and regulations respecting the same. It shall be duty of the board of chosen freeholders in each county to provide such commission with a suitable office where its maps, plans, documents, records and accounts shall be kept, subject to public inspection at such times and under such reasonable regulations as the commission may determine.

2. The director of the State Experiment Station shall be a member ex officio of each commission and shall cooperate with them for the effective carrying out of their plans and work. The said directory shall serve without compensation, except that the necessary expenses actually incurred by him in the attendance of meetings of said commissions shall be allowed and paid. He shall furnish the said commissions with such surveys, maps; information and advice as they may require for the prosecution of their work or, as in his opinion, will be of advantage in connection therewith.

3. Every such commission shall have the power to eliminate all breeding places of mosquitoes within the county wherein it is appointed, and to do and perform all acts and to carry out all plans which in their opinion and judgment may be necessary or proper for the elimination of breeding places of mosquitoes or which will tend to exterminate mosquitoes within said county.

4. Said commission shall, on or before the first day of April in each and every year, file, with the director of the State Experiment Station a detailed estimate of the moneys required for the ensuing year, and a plan of the work to be done and the methods to be employed. The said director shall have the power to approve, modify or alter the said estimates, plans and methods, and the estimates, plans and methods finally approved by him shall be by him forwarded to the board of chosen freeholders in each county on or before the first day of May following its receipt.

5. It shall be the duty of the board of chosen freeholders of each county, or other body having control of the finances thereof, to include the amount of money approved by the director of the State Experiment Station, annually in the tax levy; provided, however, that in no year shall the amount so raised exceed the amount hereinafter specified, to wit, in counties where the assessed valuations are not more than $25,000,000.00, a sum not greater than one mill on every dollar of assessed valuation; in counties where the assessed valuations are not more than $50,000,000.00, a sum not more than one-quarter of one mill on every dollar of assessed valuations.

6. The moneys so raised, or so much thereof as may be required, shall be paid from time to time to the said mosquito commission on the requisition of said commission, duly signed and approved by the president and secretary thereof.

7. It shall be the duty of each commission annually, on or before the first day of November in each year, to submit to the director of the State Experiment Station and to the board of chosen freeholders in their respective counties, a report setting forth the amount of moneys expended during the previous year, the methods employed, the work accomplished and any other information which in their judgment may seem pertinent.

8. Nothing in this act shall be construed to alter, amend, modify or repeal the provisions of Chapter 134 of the Laws of 1906, or alter, amend, modify or repeal any act now existing conferring upon state or local boards of health any powers or duties in connection with the extermination of mosquitoes in said state, but shall be construed to be supplementary thereto.

9. This act shall take effect immediately.

Approved March 21, 1912.

Since the passage of this act, which conforms essentially to the first principle set forth in this chapter, practical work of mosquito control has gone forward so satisfactorily that little further change in the law has been made.

In Chapter 288, Laws of 1915 the Director of Health of the State of New Jersey was made an ex officio member of each county mosquito extermination commission and required to cooperate with them for the effective carrying out of their plans and work.

In 1919 Chapter 123, Laws of 1919 was written into the statutes and provided merely for a change of dates on which the annual statement of plans, methods and estimates for each mosquito commission must be submitted to the Director of the New Jersey State Agricultural Experiment Station and for a change of date on or before which the Director of the New Jersey State Agricultural Experiment Station must submit his approved revision of plans, methods and estimates to the county board of freeholders. The text of Chapter 123, Laws of 1919 follows:

CHAPTER 123, LAWS OF 1919

An Act to amend an act entitled "An Act for the establishment of county mosquito extermination commissions and to define their powers and duties," approved March 21, 1912.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. Section 4 of the act of which this act is amendatory be and the same is hereby amended so that it shall read as follows:

4. Said commission shall, on or before the first day of November in each and every year, file with the director of the State Experiment Station a detailed estimate of the moneys required for the ensuing year, and a plan of the work to be done and the methods to be employed. The said director shall have the power to approve, modify or alter the said estimates, plans and methods, and the estimate, plan and method finally approved by him shall be by him forwarded to the board of chosen freeholders in each county on or before the first day of December following its receipt.

2. This act shall take effect July 1, 1919.

Approved April 11, 1919.

In 1904 an act known as Chapter 119, Laws of 1904, designating mosquito breeding as a nuisance to be eliminated by local board of health action was written in the statutes. In some respects this act is contrary to the principle set forth elsewhere in this book, in that it places the cost of elimination upon property owners on whose property the breeding occurs, in spite of the fact that the benefit of such action would be enjoyed by all persons living in the community.

Since it is logical that mosquito works should be financed from public funds, the individual has no right to set up any condition on his property that will create additional mosquito breeding places, or increase such as already exist naturally, without himself providing adequate funds which can be used by the proper public mosquito control agency to eliminate the mosquito breeding thus created. No legislative enactment directly covering this principle has been made in New Jersey. However, the board of health provision above cited in Chapter 119, Laws of 1904 and a similar power granted to mosquito commissions in Chapter 143, Laws of 1927, can be invoked against property holders who transgress this principle. The text of Chapter 143, Laws of 1927 follows:

CHAPTER 134, LAWS OF 1906

AS AMENDED BY CHAPTER 143, LAWS OF 1927

An Act to amend the title and body of an act entitled "An act to provide for locating and abolishing mosquito breeding salt marsh, and flooded areas within the State, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect," approved April twentieth, one thousand nine hundred and six.

Be it enacted by the Senate and General Assembly of the State of New Jersey: The title of the above act is hereby amended to read as follows: "An

Act to amend an act entitled 'An act to provide for locating and abolishing mosquito breeding salt marsh, fresh water swamps and flooded areas within the State, for assistance in dealing with mosquito breeding places, and appropriating money to carry its provisions into effect.' "

1. It shall be the duty of the Director of the State Experiment Station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed, all the salt marsh and all the fresh-water swamps, or flooded areas within the State, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section so surveyed, and shall indicate all the mosquito breeding places found on every such area together with a memorandum of the method to be adopted in dealing with such mosquito breeding places, and the probable cost of abolishing the same.

2. It shall be the further duty of said director, in the manner above described, to survey at the request of the board of health of any city, town, township, borough, village or county mosquito extermination commission, within the State to such extent as may be necessary, any fresh-water swamp, salt marsh or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board or commission, and he shall prepare a map of such suspected area, locating upon it such nuisance in the manner provided be discovered, and shall report upon the same as hereinafter provided in section eight of this act. Requests as hereinbefore provided for in this section may be made by any board of health within the State, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

3. Whenever, in the course of a survey made as prescribed in section one of this act, it is found that within the limits of any city, town, township, borough, village or county there exist points or places where salt-marsh or fresh water mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify in writing, by personal service upon such officer or member thereof, the board of health or the mosquito extermination commission of the county within whose jurisdiction such breeding points or places occur, of the extent and location of such breeding places, and such notice shall be accompanied by a copy of the map prepared as prescribed in section one, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, or of said county mosquito commission, within twenty days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that, under Chapter sixty-eight of the Laws of one

thousand eight hundred and eighty-seven, as amended in Chapter one hundred and nineteen of the Laws of one thousand nine hundred and four, any water in which mosquito larvae breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito-breeding pools, be abated within a period to be stated, and which shall not be more than sixty days from the date of said notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

4. In case any owner of lands on which mosquito-breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board or said county mosquito extermination commission to proceed to abate, under the powers given in sections thirteen and fourteen of the act and its amendments cited in the preceding section, or under the powers given in the act, such nuisance in the manner provided by law.

5. If, in the judgment of the director aforesaid, public interests will be served thereby, he may set aside out of the moneys appropriated for the purposes of carrying out this act such an amount or amounts as may be necessary to abate such nuisance found existing, and to abolish the mosquito breeding places found in any municipality.

6. It shall be the duty of the said director to cause to be carried on such investigation of mosquito life history, habits and control as will, in his judgment, furnish information necessary to the successful carrying on of mosquito extermination by any agency within the State.

7. It shall also be the duty of the said director to cause to be carried on, by such means as he may deem best, the spread of information concerning the nature and results of mosquito extermination among the people of the State.

8. The mosquito extermination commission of each county shall have all the powers of local boards of health as conferred by Chapter one hundred and nineteen, Laws of one thousand nine hundred and four, and the amendments thereto as now in force insofar as the same pertain to mosquito breeding nuisances artificially created and water in which mosquito larvae breed; *provided,* that the power herein conferred on such mosquito commissions shall not extend over any land area owned by any municipality or county of the State or by the State of New Jersey. The power hereby granted shall not be construed as to limit the powers conferred on county mosquito extermination commissions by Chapter one hundred and four, Laws of one thousand nine hundred and twelve, as amended.

9. All moneys set aside out of the amount appropriated for the purpose of this act by the Director of the Agricultural Experiment Station in accordance with its provisions shall be paid out by the Comptroller of the State upon the certificates of said director that all the conditions and requirements of this act have been complied with, and in the case provided for in section

five, payments shall be made to the contractor upon a statement by the person in charge of the work, as therein prescribed, attested by said director, showing the amount due and that the work has been completed in accordance with the specifications of his contract.

10. For the purpose of carrying into effect the provisions of this act, the said Director of the State Agricultural Experiment Station shall have power to expend such amount of money, annually, as may be appropriated by the Legislature. The Comptroller of the State shall draw his warrant in payment of all bills approved by the Director of the State Experiment Station, and the Treasurer of the State shall pay all warrants so drawn to the extent of the amount appropriated by the Legislature.

11. All acts or parts of acts inconsistent with this act are hereby repealed.
Approved April 20, 1906.
Amended act approved March 28, 1927.

Of the various legal acts passed by the New Jersey Legislature relative to mosquito control the outstanding and active ones are Chapter 104, Laws of 1912 and Chapter 143, Laws of 1927. It appears that the powers granted in these acts provide for the prosecution of practical mosquito control work by county units which are financed from public funds and the activities of which are supervised by the New Jersey State Agricultural Experiment Station. Furthermore, research procedure and leadership are also provided. Experience indicates that the provisions of these two acts leave little to be desired from the standpoint of the efficient prosecution of mosquito control.

11

ECONOMIC EFFECT OF MOSQUITO REDUCTION

PROBABLY THE MOST IMPORTANT ECONOMIC EFFECT of mosquito reduction has been in the increased value of vacation lands along the seashore. It was no mere matter of chance that the Asbury Park region on the Monmouth County shore and Absecon Island in Atlantic County were developed before other vacation spots. There were no salt marshes closely adjacent to Asbury Park, and Absecon Island is swept by prevailing sea breezes, hence neither had a serious mosquito problem.

On the other hand there is a record (5) of the Berkeley Arms Hotel built about 1880 at what is now Seaside Park, said to be the finest hotel on the coast, but killed its first summer because a huge flight of mosquitoes drove the guests home. It was located at the terminus of the railroad both to New Jersey and Philadelphia, was financed by the Pennsylvania Railroad and had all the prestige of that road behind it, but it never recovered from the reputation given by that first flight of mosquitoes and was finally abandoned, and later burned down.

Today the thriving resorts of Seaside Park and Seaside Heights with an assessed value of almost four million dollars adjoin the location of that ill-fated hotel and bear testimony to the economic value of mosquito control for shore resorts.

Robert F. Engle (7) has made a study of the taxable values of all boroughs and municipalities having salt marshes within their borders or standing adjacent to salt marshes. Results are shown in Tables XII, XIII, and XIV.

The areas studied were finally classified as follows: the first where the salt marsh mosquitoes had always been scarce, the second where salt marsh mosquitoes had been greatly reduced since 1915 and in many parts made scarce, and the third where mosquitoes were troublesome, and in some cases very troublesome. Each of these groups had its yearly increase in tax valuations, between 1900 and 1915 inclusive, set up as

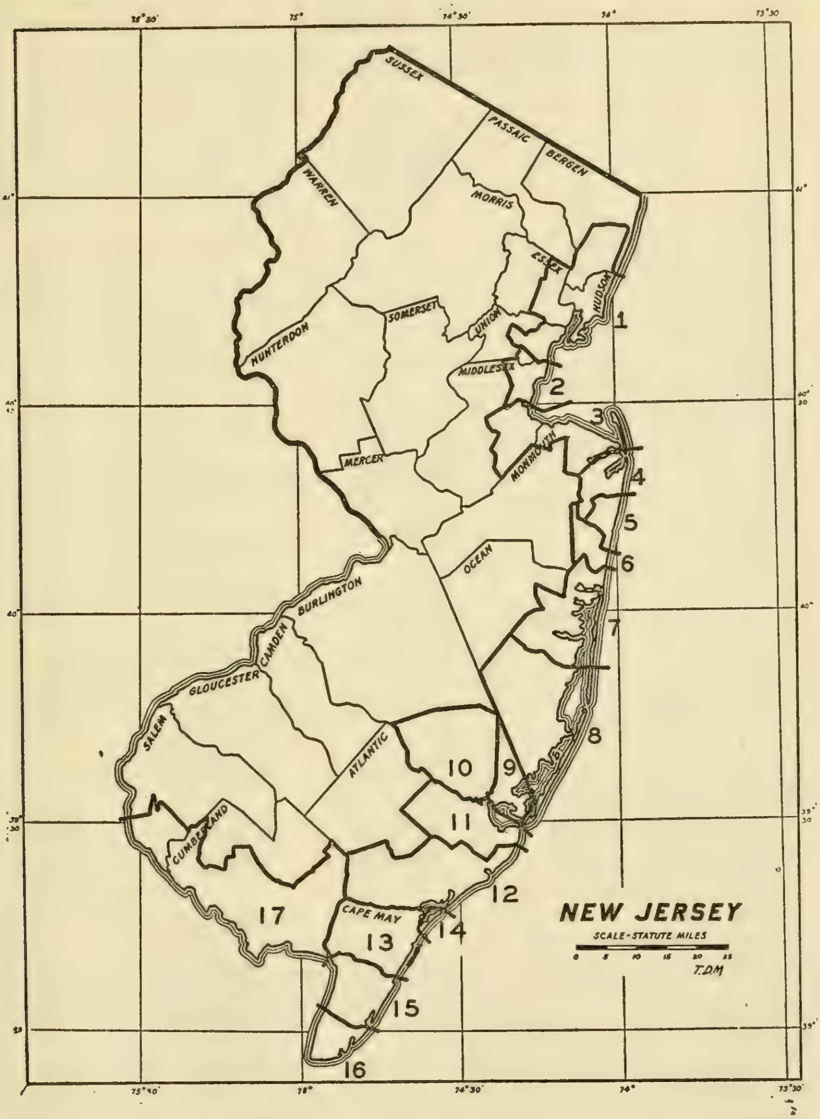
SUSSEX
PASSAIC
BERGEN
WARREN
MORRIS
ESSEX
HUDSON
SOMERSET
UNION
HUNTERDON
MIDDLESEX
MERCER
MONMOUTH
OCEAN
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
NEW JERSEY
SCALE-STATUTE MILES
0 5 10 15 20 25
T.D.M
75°30'
75°
74°30'
74°
73°30'
41°
40°30'
40°
39°30'
39°

FIG. LXXXVI. Areas designated for analysis of tax valuations, corresponding to tables in text.

the period during which mosquito control had progressed so little that tax valuations were not affected. For each group a second period, from 1915 to 1930 inclusive, was set up as the period during which tax valuations might reflect anti-mosquito work.

The table plainly shows that yearly increase in tax valuations was greatest where mosquitoes had never been very troublesome, the gain

TABLE XII

Increase of Taxable Values, a Result of Mosquito Control

Area	Net Taxable Valuation in 1900	Increase in Tax Valuation 1900–1915	Increase in Tax Valuation 1915–1930
1. Metropolitan District south to and including Linden Township.	$380,168,589	$840,054,411	$1,755,730,241
2. Rahway to Perth Amboy, inclusive.	9,799,570	29,123,472	65,580,920
3. South Amboy to Atlantic Highlands, inclusive.	9,736,428	13,813,487	27,300,084
4. Highlands to Long Branch, inclusive.	8,511,949	27,024,930	25,615,529
5. Deal Beach to Spring Lake, inclusive.	21,578,260	23,245,148	60,111,984
6. Sea Girt to Point Pleasant, inclusive.	2,075,064	2,793,734	9,409,960
7. Bay Head to Seaside Park, inclusive.	2,484,254	5,232,323	13,913,142
8. Barnegat City to Beach Haven, inclusive.	1,000,052	1,954,615	6,251,508
9. Little Egg Harbor Township Tuckerton	305,358	457,257	637,757
10. Bass River Township Washington Township	376,115	194,959	259,434
11. Galloway Township	384,570	682,479	1,098,469
12. Absecon to Longport, inclusive.	20,879,841	91,696,517	305,243,063
13. Weymouth, Upper, and Dennis Townships.	1,105,783	1,197,472	1,254,468
14. Ocean City.	1,870,000	7,008,983	30,136,239
15. Sea Isle City to Stone Harbor, inclusive.	1,339,280	4,814,982	5,950,366
16. Wildwood to West Cape May, inclusive.	2,718,323	17,296,744	28,339,315
17. Delaware Bay Coast of Cumberland and part of Salem Counties.	4,481,044	945,995	1,795,206

was only slightly less in areas where mosquitoes had been brought under control, and the gain in areas where mosquitoes have not been brought under control at all, or only recently, is much less than either of the other groups.

It may be said conservatively that the area in which mosquitoes have

TABLE XIII

Average Annual Increase in Tax Valuations

Area	Nature of Area	Mosquitoes	Yearly Increase in Tax Valuations in $100,000 Units	
			1900–1915	1915–1930
1	Urban and Industrial	Scarce since 1915	560.4	1170.5
2	Urban and Industrial	Scarce since 1915	19.4	43.7
3	Shore Resort and Industry	Scarce since 1915	9.2	18.2
4	Shore Resort	Scarce since 1915	18.0	17.1
5	Shore Resort	Scarce always	15.5	40.1
6	Shore Resort	Scarce since 1915	1.9	6.3
7	Shore Resort	Scarce since 1915	3.5	9.3
8	Shore Resort	Troublesome	1.3	4.2
9	Shore Resort and Industry	Very troublesome	0.3	0.42
10	Agriculture	Very troublesome	0.13	0.17
11	Shore Resort and Agriculture	Troublesome	0.45	0.73
12	Shore Resort and Agriculture	Scarce since 1915	61.1	203.5
13	Shore Resort and Agriculture	Troublesome	0.73	0.84
14	Shore Resort	Rarely troublesome since 1915	3.2	4.0
15	Shore Resort and Agriculture	Troublesome	4.7	20.1
16	Shore Resort and Agriculture	Troublesome	11.5	18.9
17	Agriculture	Troublesome	0.63	1.2

been greatly reduced since 1915 shows a gain of $555,345,000 over what could be expected had the mosquitoes in that area not been brought under control. The writer believes this is a conservative statement because the areas included were simply those that either had salt marshes within their borders or stood immediately adjacent to salt marshes, and as has been stated, since the flight of the salt marsh mosquitoes extends many miles back from the coast, mosquito freedom occurs far inland beyond the borders of the boroughs and municipalities taken into consideration in this study.

The total assessed value from Highlands to Cape May, of the beaches, and such mainland sections of townships, as are needed for the present and future growth of resorts in 1900 was $64,628,849; in 1915, $248,229,992; in 1930, $736,451,226; an increase of 671 and three-fourths millions in 30 years, or 11.39 times. In the same time,

TABLE XIV

Summary

Area	Mosquitoes	Yearly Increase in Tax Valuations in $100,000 Units 1900–1915	1915–1930	Ratios of First Period to Second
5	Scarce always	15.5	40.1	1: 2.59
1, 2, 3 4, 6, 7 12, and 14	Greatly reduced since 1915 and in many parts scarce.	677.8	1448.6	1: 2.20
8, 9, 10 11, 13, 15 16, and 17	Troublesome in varying degrees, some places very troublesome	18.4	30.4	1: 1.65

the valuations of the balance of the state only increased 6.84 times. It is doubtful whether more than ten per cent of the resort possibilities of this area have been developed.

	Ratios of Increase 1900–1915	Ratios of Increase 1900–1930
Seashore	1: 3.84	1: 11.39
Balance of state	1: 2.82	1: 6.84
Whole state	1: 2.90	1: 7.18

The writer (12) made a study of tax valuation increase in Cumberland, Cape May, Atlantic, Ocean, and Monmouth Counties from 1895 to 1935 inclusive. The purpose of this study was to see whether there existed any correlation between salt marsh mosquito prevalence and tax valuation increase. In Cumberland there has been no extensive effective mosquito control, in Cape May the work of mosquito control has just well begun, in Atlantic most of the salt marsh has been ditched, in Ocean the ditching of the salt marsh is not as complete as in Atlantic, and in Monmouth such salt marshes as exist are pretty well ditched. Prior to 1915 mosquito control work had not reached the point to affect the taxable values.

In Cumberland where mosquitoes are present in their old time numbers county valuation increases have outstripped the shore valuations, while in the other counties, where mosquitoes have been reduced, shore valuations have outstripped county valuations.

S. D. Walker (30), a real estate authority, says, "There is no question in my mind that millions of dollars in assessments have been lost to the State of New Jersey in the past, because of the famous or infamous New Jersey mosquitoes. Within recent years I have been personally in contact with several deals running up into the millions where the mosquitoes, as a condition of environment, made or broke the deal.

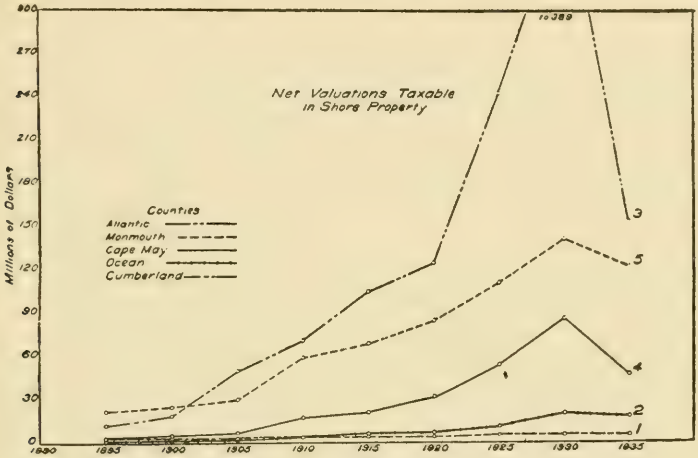

FIG. LXXXVII. Chart of tax valuation increases.

"A property on Barnegat Bay was sold for some two million dollars. The closing of this deal was held up very nearly a month until the purchasers received full reports as to the possibility of freeing this particular section from mosquitoes, and I feel confident that if the mosquito control work in that county had not been in the advanced stage which it was, these capitalists could not have been induced to purchase this tract."

In the last twenty-five years there have been three instances where malaria has been practically eliminated from sections where 100 or more cases were experienced in a single year. The first was in Franklin, Sussex County, where David Jenkins (16) has shown how this elimination of malaria was accomplished by eliminating the breeding of *Anopheles quadrimaculatus.* The second occurred in Mercer County near Princeton (6). The third case is recent and occurred in Camden County, where there were 110 cases of malaria the first year and two cases of malaria the second year. *This experience leaves no doubt in our minds that malaria can be readily eliminated by the control of the Anopheles mosquito which serves as a vector for this disease, but the control of such things as fowlpox of chicken, encephalomyelitis of horses and heart worm of dogs by elimination of the mosquito carrying the infection has not yet been worked out.*

REFERENCES

(1) Atkins, R. W. A., 1923. "The phosphate content of fresh and salt waters in its relation to growth of Algal plankton." *Jl. Marine Biol. Assoc. United Kingdom,* v. 13, p. 119.

(2) Atkins, R. W. A. and Harris, 1924. "Seasonal changes in water and Heleo-plankton of fresh water ponds." *Sci. Proc. Roy. Dublin Soc.,* v. 18 (n.s.) p. 1.

(3) Britton, W. E. and H. L. Viereck, 1905. "Report on mosquito investigations. 4th Rept. State Entomologist of Connecticut." *Conn. Agr. Exp. Sta. Rpt. for 1904,* pp. 253–310.

(4) Chidester, F. E., 1916. "A biological study of the more important of the fish enemies of the salt marsh mosquitoes." *Bul. N. J. Agr. Exp. Sta.,* no. 300.

(5) Clarke, J. Lyell, 1937. "New and significant experiences in mosquito control in the DesPlaines Valley Mosquito Abatement District." *Proc. 24th Ann. Meet. N. J. Mosq. Exter. Assoc.,* pp. 112–126.

(6) Dahlgren, Ulric, 1917. "Mosquitoes and malaria in Princeton." *Proc. 4th Ann. Meet. N. J. Mosq. Exter. Assoc.,* pp. 158–163.

(7) Engle, Robert F., 1933. "Mosquitoes, then and now—prevalence and effect on seashore business and real estate." *Proc. 20th Ann. Meet. N. J. Mosq. Exter. Assoc.,* pp. 12–24.

(8) Ginsburg, Joseph M., 1937. "Principles underlying the protection of outdoor meetings from the mosquito pest and methods of application." *Proc. 24th Ann. Meet. N. J. Mosq. Exter. Assoc.,* pp. 5–11.

(9) Headlee, Thomas J., 1915. "The mosquitoes of New Jersey and their control." *Bul. N. J. Agr. Exp. Sta.,* no. 276.

(10) ———, 1921, "The mosquitoes of New Jersey and their control." *Bul., N. J. Agr. Exp. Sta.,* no. 348.

(11) ———, 1934. "Mosquito work in New Jersey for the year 1933." *Proc. 21st Ann. Meet. N. J. Mosq. Exter. Assoc.,* p. 34.

(12) ———, 1937. "Mosquito problems." *Proc. 24th Ann. Meet. N. J. Mosq. Exter. Assoc.,* pp. 228–236.

(13) Howard, L. O., 1901. *Mosquitoes, how they live, how they carry disease, how they are classified, how they may be destroyed.* McClure, Phillips and Company, New York.

(14) Howard, L. O., H. G. Dyar, and F. Knab, 1912. *The mosquitoes of North and Central America and the West Indies.* 3 vol., Carnegie Inst. Wash., Washington, D. C.

(15) Hunt, Ralph, 1916. "Progress on mosquito control in New Jersey." *Proc. 3rd Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 78–86.

(16) Jenkins, David, 1938. "Address of the president." *Proc. 25th Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 5–10.

(17) LePrince, J. A. and A. J. Orenstein, 1916. *Mosquito control in Panama*, Putnam, New York.

(18) Matheson, Robert, 1929. *A handbook of the mosquitoes of North America.* Charles C. Thomas, Springfield, Ill.

(19) Rudolfs, Willem, 1922. "Chemotropism of mosquitoes." *Bul. N. J. Agr. Exp. Sta.*, no. 367.

(20) ———, 1924. "Mosquito breeding in specific places." *Journ. of Parasitology*, v. 11, pp. 79–83.

(21) ———, 1925. "The food of mosquito larvae." *Proc. 12th Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 25–30.

(22) ———, 1926. "Investigation of mosquito problems carried on at the New Jersey Agricultural Experiment Station during the past year." *Proc. 13th Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 35–51.

(23) Smith, John B., 1904. *Report of the New Jersey Agricultural Experiment Station upon the mosquitoes occurring within the state, their habits, life history, etc.* New Brunswick, N. J.

(24) ———, 1905. *Report of the New Jersey Agricultural Experiment Station for year ending October 31, 1905*, pp. 681–684.

(25) ———, 1907. *Report of the New Jersey Agricultural Experiment Station for year ending October 31, 1907*, pp. 546–557.

(26) ———, 1908. *Report of the New Jersey Agricultural Experiment Station for year ending October 31, 1908*, pp. 418–421.

(27) ———, 1909. "Report of the insects of New Jersey." *Ann. Rept. N. J. State Museum.*

(28) Thibault, James K., Jr., 1910. "Notes on the mosquitoes of Arkansas." *Proc. Ent. Soc. Wash.*, vol. 12, pp. 13–26.

(29) Vannote, Robert L., 1937. "Methods of applying the larvicide as a repellent." *Proc. 24th Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 11–13.

(30) Walker, S. D., 1933. "The status of mosquito control in the public mind." *Proc. 20th Ann. Meet. N. J. Mosq. Exter. Assoc.*, pp. 24–38.